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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1934

THE REALM OF THE NEBULAE

By Dr. EDWIN HUBBLE

MOUNT WILSON OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON

THE EXPLORATION OF SPACE

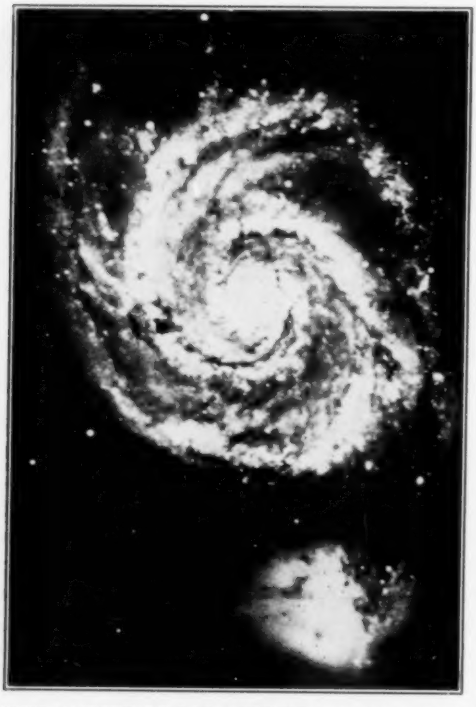
I PROPOSE to discuss some of the recent explorations in the realm of the nebulæ which bear directly on the structure of the universe. The earth we inhabit is a member of the solar system. The sun with its family of planets seems isolated in space, but the sun is merely a star—one of the millions which populate our particular region of the universe. The stars are scattered about at enormous intervals, but on a still greater scale they are found to form a definite system, again isolated in space. On the grand scale we may picture the stellar system drifting through the universe as a swarm of bees drifting through the air.

From our position somewhere within the system, we look out through the swarm of stars, past the borders, into the universe beyond. It is empty for the most part—vast stretches of empty space. But here and there, at immense intervals, we find other stellar systems, comparable with our own. They are so distant that in general we do not see the individual stars. They appear as faint patches of light and hence are called nebulæ, *i.e.*, clouds.

The nebulæ are great beacons, scattered through the depth of space. We see a few that appear large and bright. These are the nearer nebulæ. Then we find them smaller and fainter in constantly increasing numbers, and we know we are reaching out into space farther and ever farther until, with the faintest nebulæ that can be detected with the greatest telescope, we have reached the frontiers of the known universe. This last horizon defines the Observable Region—the region of space which can be explored with existing telescopes. It is a vast sphere, some 600 million light years in diameter, throughout which are scattered 100 million nebulæ.

The question immediately arises as to whether the nebulæ form an isolated super-system, analogous to the system of the stars but on a still grander scale. Actually, we find the nebulæ scattered singly, in groups and occasionally in great clusters, but when very large volumes of space are considered, the tendency to cluster averages out and to the very limits of our telescopes the distribution is approximately uniform. If the observable region is divided into 100, 1,000 or even 10,000 equal parts, the nebular contents of the various fractions are very closely similar. There is no evidence of a thinning out, no trace of a physical boundary. The realm of the nebulæ, we must conclude, stretches on and on, far beyond the frontiers.

Observations give not the slightest hint of a super-system of nebulæ. Hence, for purposes of speculation, we may invoke the principle of the uni-



THE "WHIRLPOOL NEBULA" (M. 51 IN CANES VENATICI)

THIS, THE FIRST NEBULA IN WHICH THE SPIRAL STRUCTURE WAS DISCERNED, IS ABOUT ONE MILLION LIGHT YEARS FROM THE EARTH. (TAKEN AT MT. WILSON OBSERVATORY OF CARNEGIE INSTITUTION.)

formity of nature and suppose that any other equal portion of the universe, chosen at random, will exhibit much the same general characteristics as the region we can explore with our telescopes. As a working hypothesis, serviceable until it leads to contradictions, we may venture the assumption that the realm of the nebulæ is the universe—that the Observable Region is a fair sample and that the nature of the universe may be inferred from the observed characteristics of the sample.

CHARACTERISTICS OF THE OBSERVABLE REGION

The characteristics of the Observable Region as a whole forms the main subject of the present discussion, but a brief appendix will be added, indicating the kind of information concerning the universe we may hope to infer from the sample.

We are situated, by definition, at the center of the Observable Region. Our immediate neighborhood—the system of the planets—we know rather intimately, but our knowledge fades rapidly with increasing distance. We know something about the stars, a little about the nearer nebulæ, almost nothing about the more remote nebulæ save their directions, their apparent luminosities and the nature of the light which they emit. Information concerning the Observable Region as a whole is thus restricted to the most general features only—the distribution of nebulæ and the more conspicuous characteristics of their spectra. These data, together with the general laws of nature, which we assume to hold everywhere, are our present clues to the nature of the universe.

Let us start with distribution. The nebulæ are beacons scattered through space. In order to determine their distribution it is necessary to know their intrinsic luminosity, *i.e.*, their candle power—both the average luminosity and the range. If some nebulæ were intrinsically a million times brighter than others, as is the case with stars, the problem of the distribution would be extremely difficult, for apparent faintness would then be a very poor indication of distance. Fortunately, the nebulæ are all of the same order of intrinsic luminosity. This information was derived as follows.

DISTANCES OF NEBULÆ

The nebulæ are stellar systems, and some of them are so near that a few of the individual stars can be detected with the modern reflectors. Stars are the fundamental criteria of nebular distances. We know something about stars and wherever we find them we can gen-

erally recognize their types, estimate their candlepowers, and so derive their distance from their apparent faintness. In a dozen of the nearest nebulæ, various types of stars are clearly recognized and distances are rather accurately determined.

For instance, some 40 cepheid variable stars are found in M31, the great spiral nebula in Andromeda. Such stars in our own system average about 3,000 times as bright as the sun. In the spiral they appear about 150,000 times fainter than the faintest star that can be seen with the naked eye. A simple calculation indicates that the spiral must lie at a distance of nearly a million light years. Other types of stars which can be recognized in the nebula indicate the same order of distance, and hence we consider that the results are reliable. Such accuracy, however, is attained only for a very few of the nearest nebulæ.

In several dozen other nebulæ we can detect a few stars, but can not recognize their types. Nevertheless, we have many reasons for supposing that there is an upper limit of stellar luminosity and that this limit, about 60,000 times as bright as the sun, is in general attained and seldom surpassed in all the great systems of stars. Hence we may assume that the brightest stars in all nebulæ are 60,000 times as bright as the sun and estimate their distances from their apparent faintness. The results may not be accurate individually, but they are reliable for statistical purposes.

Finally, the great cluster in Virgo, a compact group of several hundred nebulæ, is so near that a few stars can be seen in a few of its members. These stars indicate the distance of all the several hundred nebulæ in the cluster. The twenty known clusters, moreover, are all similar groups, and their relative distances were already known. Hence the distance of the Virgo cluster indicates the distances of them all.

In this way it has been possible to assemble a sample collection of several thousand nebulæ whose distances and hence whose real luminosities and dimensions are known. An analysis of the sample collection indicates at once that the nebulæ are all of the same order of luminosity. They average about 80 million times as bright as the sun. The brightest are about 10 times brighter than the average and the faintest are about 10 times fainter, but the majority fall within the narrow limits from a half to twice the average of them all. The mean of any considerable number, say 100 nebulæ, chosen at random will be closely similar to the general average. For statistical purposes, where large numbers are concerned, we may assume that the nebulæ are equally luminous and that their apparent faintness indicates their distances.

Distribution of Nebulæ

The distribution of nebulæ can therefore be studied by counting the numbers

SPIRAL NEBULA IN URSA MAJOR
(M. 101)

THE REGION OF SPACE WHICH CAN BE EXPLORED WITH EXISTING TELESCOPES IS A VAST SPHERE, 600 MILLION LIGHT YEARS IN DIAMETER, THROUGHOUT WHICH 100 MILLION NEBULÆ ARE SCATTERED. (TAKEN AT MT. WILSON OBSERVATORY.)

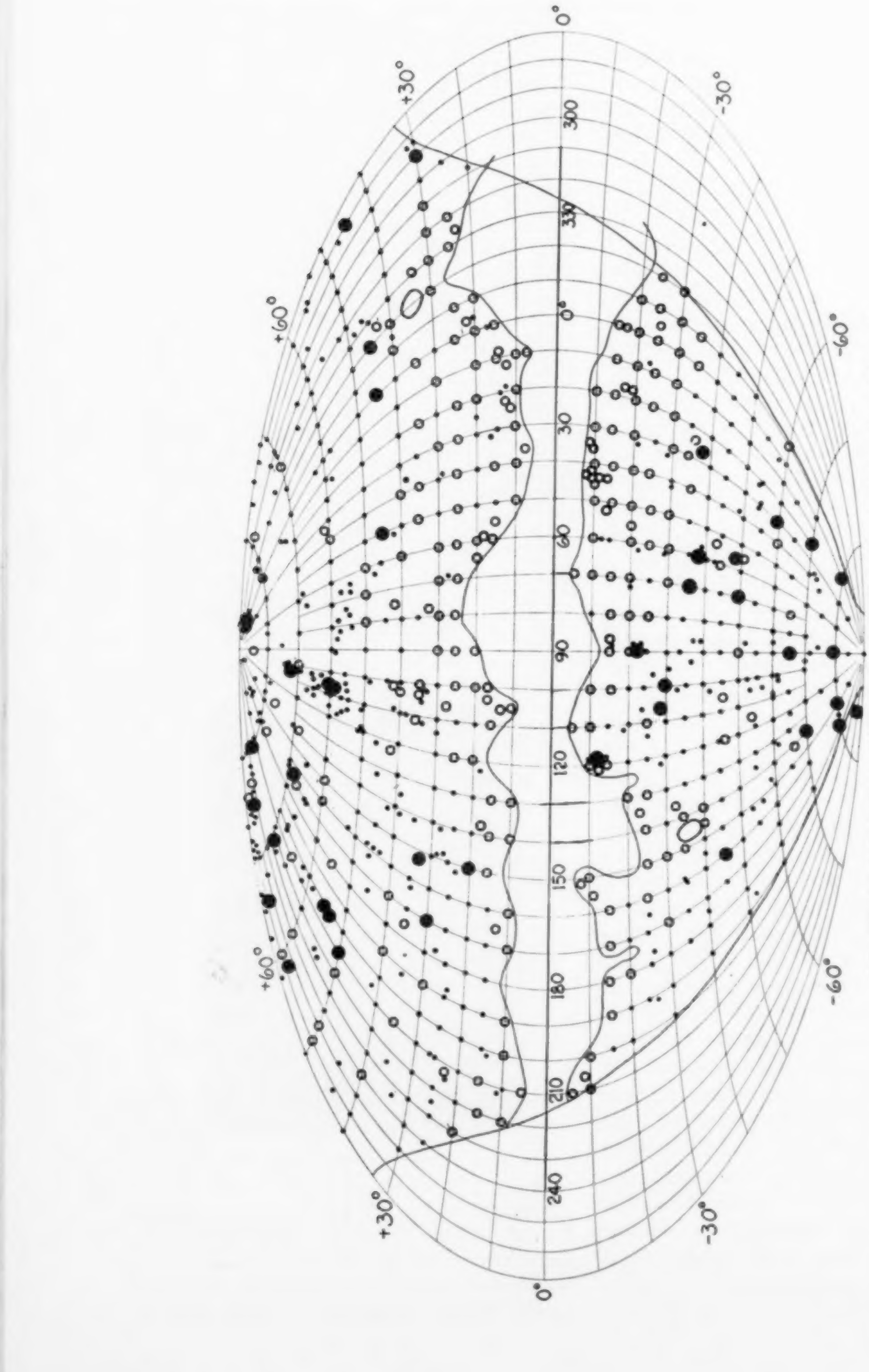


DIAGRAM SHOWING THE DISTRIBUTION OF SPIRAL NEBULÆ

FROM COUNTS MADE BY DR. HUBBLE ON PHOTOGRAPHS DISTRIBUTED AT INTERVALS OVER THE WHOLE NORTHERN SKY. THE HORIZONTAL LINE IS THE PLANE OF THE GALAXY, AND THE FIGURES GIVE GALACTIC LONGITUDE. IT SHOULD BE NOTED THAT SPIRALS AVOID THE REGION OF THE GALAXY.

of nebulæ to successive limits of apparent faintness. The results represent numbers of nebulæ in spheres of successively greater radii, and the differences give the numbers of nebulæ in successive spherical shells. In this way the numbers of nebulæ per unit volume, *i.e.*, the density distribution of nebulæ, has been explored throughout the observable region. To a first approximation the density distribution is uniform. Each volume of space, represented by a sphere with a radius of 10 million light years, contains on the average about 2,500 nebulæ. Each nebula is about 80 million times as bright as the sun and perhaps 800 million times as massive. On the average, the nebulæ are about one and a half million light years apart.

The uniform distribution of nebulæ means that, on the grand scale, the density of matter in space is uniform and we can calculate the density. There is, on the average, one nebula, 800 million times as massive as the sun, for every billion billion cubic light years or roughly one sun per billion or thousand million cubic light years. In ordinary units this is equivalent to one gram per 10^{30} cubic centimeters, and may be visualized as corresponding to a grain of sand in each volume of space equal to the volume of the earth. The nebulæ are scattered very thinly, and space is mostly empty.

In this calculation we consider only the matter concentrated in nebulæ. There is doubtless matter scattered between the nebulæ which has been ignored. How much, we do not know; we can only say that there is not sufficient to be detected—not enough to appreciably dim the most distant nebulæ that can be observed.

Velocity-Distance Relation

The second characteristic of the Observable Region, the velocity-distance relation, introduces the subject of spectrum analysis. When a light source is viewed through a glass prism, the various colors of which the light is composed are spread out into an ordered sequence, represented, for instance, in the rainbow. The sequence never varies, each color has its place. Different colors represent light of different wave-lengths. From the short waves of violet light, the waves lengthen steadily through the spectrum to the long waves of the red at the other end.

Three kinds of spectra are generally distinguished. An incandescent solid, e.g., electric light filament, radiates all possible colors or wave-lengths; hence its spectrum is continuous from violet to red.

An incandescent gas, *e.g.*, a neon tube, radiates only a few isolated colors, hence its spectrum consists of isolated bright spots or lines distributed in a certain pattern. This is called an emission spectrum. The pattern of bright lines is characteristic of the particular gas involved, and unknown gases are very readily identified from their spectra alone.

Finally, there are absorption spectra. When an incandescent solid, giving, of course, a continuous spectrum, is surrounded by a cooler gas, *e.g.*, a star surrounded by an atmosphere, the gas absorbs just those colors which it would radiate if itself incandescent. This absorption produces dark spaces or lines in the otherwise continuous spectrum of the background. The patterns of these dark lines identify the gases in the atmospheres of the stars.

The study of absorption spectra is the dominating feature of modern astronomy. They furnish an astonishing amount of information concerning the physical condition of stars and even of planets and of nebulæ. Either directly or indirectly they indicate surface temperatures of stars, surface luminosities, total luminosities, distances, velocities in the line of sight.

The significance of spectra may be indicated by a homely demonstration.

ONE OF THE MOST BEAUTIFUL OF THE SPIRAL NEBULÆ (M. 81 IN URSA MAJOR)

ITS LIGHT TAKES 1,600,000 YEARS TO REACH US. THE CENTRAL REGION IS UNRESOLVED BUT IN THE OUTER PORTIONS SWARMS OF STARS ARE VISIBLE. THESE ARE SIMILAR TO THE VERY BRIGHT STARS IN OUR OWN GALACTIC SYSTEM. (TAKEN AT MT. WILSON OBSERVATORY.)

From Mt. Wilson the lights of some sixty cities and towns are visible, spread over the valley below. A direct photograph with a camera shows swarms of lights similar to a field of stars, but tells nothing as to the nature of the lights. When a glass prism is placed in front of the camera lens, each light is spread out into a spectrum. Then the differences appear. The filament lamps show continuous spectra, arc lights show the emission spectra of carbon vapor, neon signs show two or three isolated colors. In the same way a direct photograph of the sky shows a field of stars. Except for their different luminosities the stars all appear alike. A photograph of the same field, with a prism in front of the lens, shows each star drawn out into its spectrum, and differences in the nature of the light are at once apparent.

Yellow stars like the sun show the absorption of hydrogen and of iron vapor in their atmospheres and, near the violet end, a pair of strong dark lines due to calcium absorption. These latter, the H and K lines of calcium, are the most conspicuous feature of the spectra and are unmistakable wherever they are found. On the same scale, the spectra of nebulæ resemble those of yellow stars. The H and K lines are readily recognized, and certain hydrogen and iron lines as well.

The spectra of nebulæ, however, exhibit a peculiar characteristic in that the details—the dark lines—are not in their usual positions. The lines are all displaced toward the red end of the spectrum and the displacements increase with the faintness of the nebulæ observed. The observations are summed up in the statement—the fainter the nebula, the larger the red-shift.

Now apparent faintness of nebulæ is confidently interpreted in terms of distance; hence we can restate the observational results in the form—red-shifts increase with distance. Precise investigations indicate that the relation is linear—red-shifts are equal to distances times a certain constant.

The relation was first established about five years ago among the brighter nearer nebulæ for which Dr. Slipher, of the Lowell Observatory, had assembled his collection of spectra representing the pioneer work in the field. Since then the list of spectra has been more than trebled by Mr. Humason, using the large reflectors on Mt. Wilson. With the 150 red-shifts now available, the distance relation has been confirmed and extended to the limit at which spectra can be recorded with existing instruments. Out to 150 million light years, the red-shifts increase at a uniform rate.

The significance of this strange characteristic of our sample of the universe

depends upon the interpretation of red-shifts. The phenomena may be described in several equivalent ways—the light is redder, the light waves are longer, the vibrations are slower (the pitch is lower), the light quanta have lost energy.

Many ways of producing such effects are known, but of them all only one will produce large red-shifts without introducing other effects which should be conspicuous but actually are not found. This one known permissible explanation interprets red-shifts as due to actual motion away from the observer. Rapid motion of recession drags out the light waves and, as it were, lowers the pitch. Red-shifts, we can say, are due either to actual motion or to some hitherto unrecognized principle of physics. Theoretical investigators almost universally accept the red-shifts as indicating motion recession of the nebulæ, and they are fully justified in their position until evidence to the contrary is forthcoming.

On this interpretation the nebulæ are rushing away from us, and the farther away they are, the faster they are traveling. The velocities increase by roughly 100 miles per second for each million light light years of distance. The present distribution of nebulæ can be represented on the assumption that they were once jammed together in our particular region of space, and at a particular instant, about 2,000 million years ago, they started rushing away in all directions at various velocities. The slower nebulæ, on this assumption, are still in our neighborhood, but the faster nebulæ are now far away. The faster they are traveling the farther they have gone. The time scale seems suspiciously short—a small fraction of the estimated age of some stars—and the apparent discrepancy suggests the advisability of further discussion of the interpretation of red-shifts as evidence of motion.

The largest red-shift actually recorded represents a velocity of about 15,000 miles per second at a distance of roughly 150 million light years. But nebulæ can be photographed out to distances twice or thrice the distances to which their spectra can be recorded. Hence, if the observed relation holds to the very frontiers of the observable region, we should encounter red-shifts corresponding to velocities of 30 or 40 thousand miles per second, say one fifth the velocity of light.

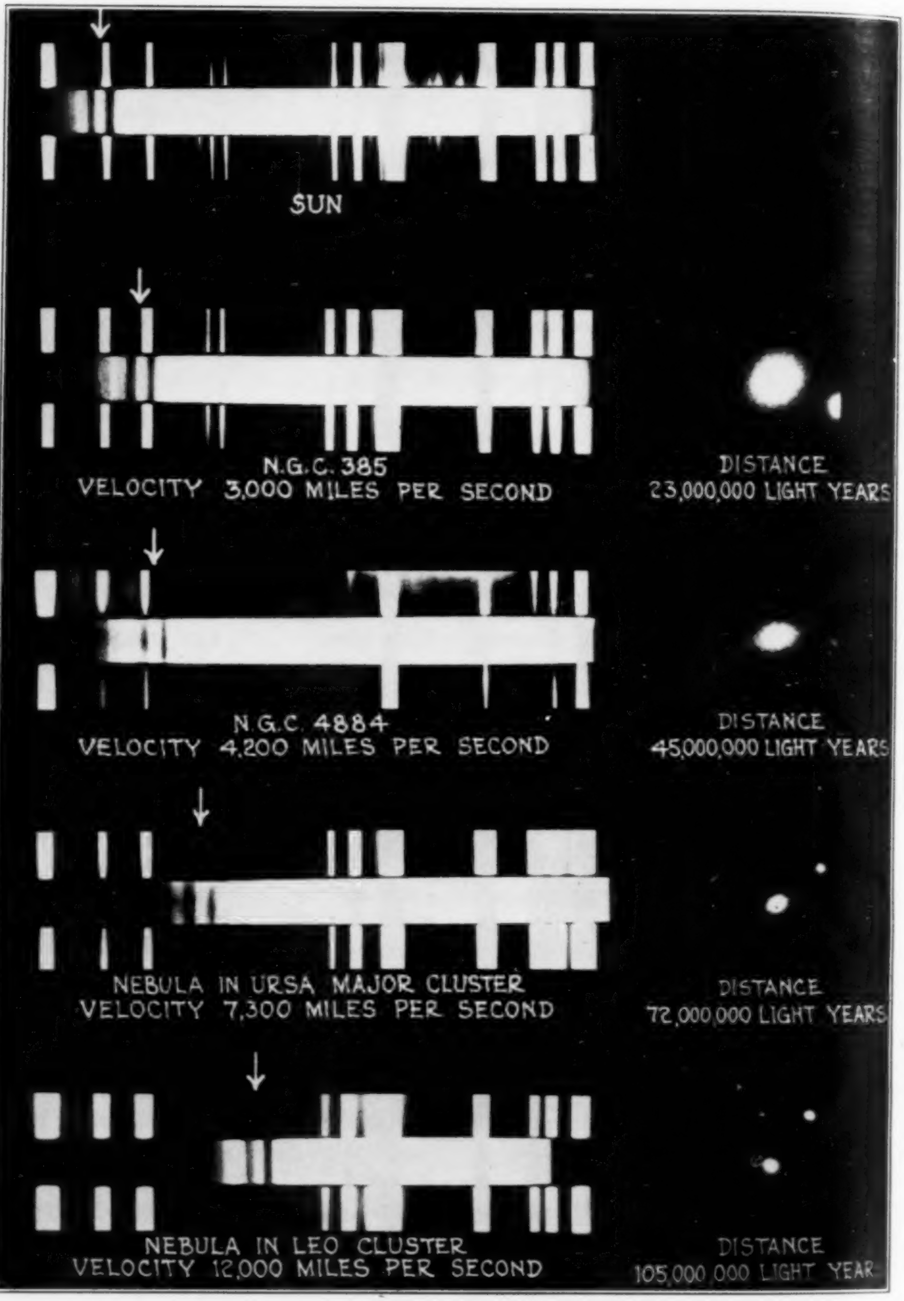
Such red-shifts are so enormous that we may expect appreciable indirect effects on colors and apparent luminosities. These effects are now under investigation. The field is new, but it offers very definite prospects not only of testing the form of the velocity-distance relation beyond the reach of the spectrograph, but even of critically testing the interpretation of red-shifts as actual motion. With this possibility in view, the cautious observer refrains from committing himself to the present interpretation and employs the colorless term "apparent velocity."

The Observable Region as a Sample of the Universe

Now, in conclusion, let us see what sort of information concerning the universe may be inferred from the observed characteristics of the sample. The sample is homogeneous and isotropic and the nebulæ appear to be rushing away from our particular position. These meager data, together with the general laws of nature, are all we have to guide us.

Mathematics deals with possible worlds, *i.e.*, logically consistent systems. Science attempts to determine the actual world in which we live. So, in cosmology, mathematics presents us with an infinite array of possible universes. The explorations of science are eliminating type after type, class after class, and already the residue has dwindled to more or less comprehensible dimensions.

Considerations of the laws of nature



WIDENED LOW-DISPERSION SPECTRA

WITH DIRECT PHOTOGRAPHS OF DISTANT EXTRA-GALACTIC NEBULÆ SHOWING LARGE RED SHIFT AND GIVING ESTIMATED RECESSION VELOCITIES. (TAKEN AT MT. WILSON OBSERVATORY.)

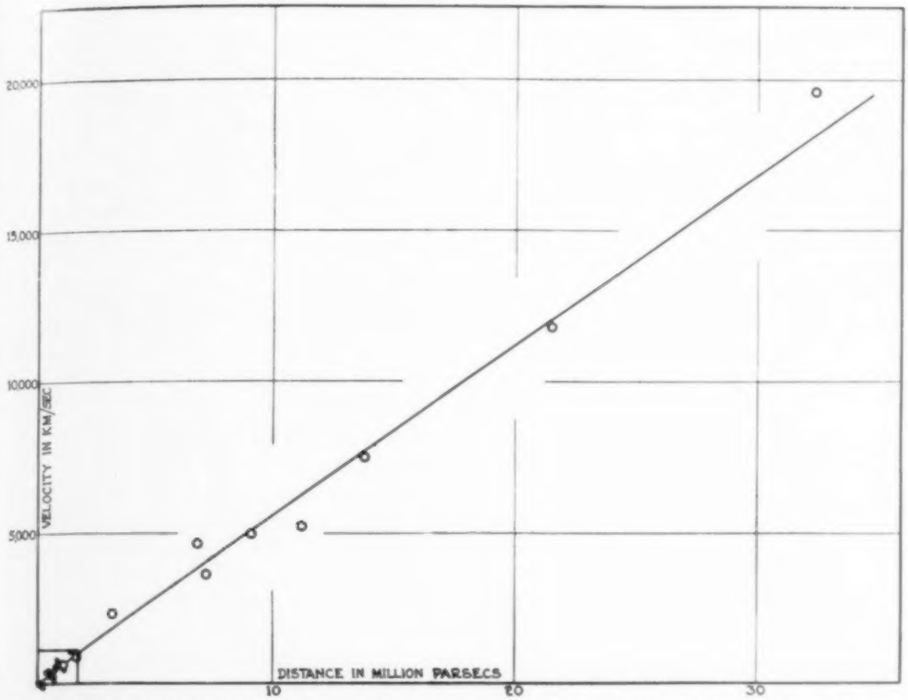


DIAGRAM SHOWING RELATION BETWEEN MEASURED VELOCITY AND DISTANCE OF SPIRAL NEBULÆ

THE VELOCITY IS MEASURED FROM SPECTROGRAMS TAKEN WITH THE 100-INCH REFLECTOR AT MT. WILSON OBSERVATORY AND THE DISTANCE IS DETERMINED FROM THE BRIGHTNESS OF THE NEBULÆ AS SHOWN ON DIRECT PHOTOGRAPHS.

led to the theory of relativity, developed by the genius of Einstein and now generally accepted. According to relativity, the large-scale geometry of space is determined by the contents of space. This dependence is expressed in Einstein's famous cosmological equation and modern cosmology is largely a series of attempts to solve the equation. It is a relation between symbols, and solutions are not possible until the symbols are interpreted. Observations as yet furnish only partial interpretations, and hence the various solutions already proposed incorporate a certain amount of guessing.

The most reasonable speculations run about as follows. Since the contents of space is distributed uniformly, the geometry of space must exhibit the same uniformity. Of all possible geometries, only three types fulfil this requirement completely. One is Euclidean geometry, so familiar to most of us that we ignore the very existence of others. Another is Riemannian geometry, and this it is which the consensus of opinion accepts as the most useful for describing the large-scale features of the universe.

Riemannian space with constant positive curvature follows more or less directly from the observed characteristics of our sample. This space is usually described as the three-dimensioned analogue of the sphere. Just as the surface of a sphere with its uniform positive curvature has a finite area but no boundaries, so the three-dimensional analogue,

with its uniform positive curvature, has a finite volume but no boundaries. In other words, we live in a finite universe.

The volume is determined by the radius of curvature (again like the area of the surface of a sphere) and the radius of curvature is determined by the amount of matter, *i.e.*, the density of matter, in space. The density actually observed, 10^{-30} grams per cubic centimeter, suggests a radius of about 3,000 million light years and a volume of the order of two or three million times the volume of the Observable Region. Such a universe would contain about 500 million million nebulæ. This is an instantaneous picture, representing the situation for the past 200 or 300 million years.

The conception of a homogeneous universe with a definite volume and definite contents seems moderately comfortable until we remember the red-shifts. The conception is derived from relativity, and relativity assumes that the universe will appear much the same no matter where the observer happens to be situated. Since the nebulæ appear to be rushing away from our particular position, they will appear to be rushing away from any other position in which an observer is located. This apparent anomaly is explained on the theory that the universe is expanding. The radius of curvature is a function of the time and is now increasing. The volume is increasing and the density is diminishing. The conventional analogy in two dimensions is again with the surface of a sphere, say a rubber balloon which is being inflated. From each point on the surface, all other points are retreating and, within certain limits, the farther away they are, the faster they recede.

The expanding universe, with its momentary dimensions as previously described, is the latest widely accepted development in cosmology. Various refinements as to the nature of the expansion have been discussed at length, but always with the aid of additional assumptions concerning the validity of which there is no consensus of opinion. Even the present position depends absolutely upon the interpretation of red-shifts as Doppler effects representing actual motions.

Further radical advances in cosmology will probably await the accumulation of more observational data—the elimination of more types of possible worlds. The data will come either from more detailed investigations of the present Observable Region or from a significant enlargement of the region itself.

The latter alternative will be achieved with the 200-inch reflector in course of construction for the California Institute of Technology, with the assistance and cooperation of the Carnegie Institution of Washington. This great telescope, in the hands of experienced research men in the two institutions, is expected to enlarge the available sample of the universe some ten times in a single step and will increase in a corresponding measure the chances that our sample is fair and significant.

I believe the 200-inch will definitely answer the question of the interpretation of red-shifts, whether or not they represent actual motions, and if they do represent motions—if the universe is expanding—the 200-inch may indicate the particular type of expansion.

This prospect is the climax of the story. Our present information concerning the universe is necessarily vague. It is new and raw and will mature only with time and continued study. The great significant feature is that the first steps have actually been achieved—that in our generation, for the first time, the structure of the universe is being investigated by direct observations.

SOME MORTUARY CUSTOMS OF THE WESTERN ALASKA ESKIMOS

By CLARK M. GARBER

FORMERLY PROFESSOR OF BIOLOGICAL SCIENCES AT CAPITAL UNIVERSITY; FORMERLY SUPERINTENDENT OF ESKIMO AND INDIAN SCHOOLS IN ALASKA FOR THE UNITED STATES BUREAU OF EDUCATION; BUTLER, OHIO

ALTHOUGH in recent years there has been considerable stimulation behind the archeological and anthropological study of the western Eskimos no ethnological and sociological investigations concerning the cultures of these people have been made since Petrof (1880) and Nelson (1877–1890). This article, therefore, has for its purpose the supplementing of any previous studies conducted along this line and is not intended as a criticism or correction of the results of any former ethnological investigations. The author has long ago recognized that the aboriginal peoples of western Alaska are rapidly becoming Americanized by reason of their increasing contacts with the white race. Hence, if much of this valuable information is to be preserved for the benefit of future generations, it must be done now. This dissertation is a part of the product of the author's eight years of study and experience during an intimate contact with these people. As indicated by the title of this article the present study will be confined to an examination of the mortuary practises which have been racial customs among the western Eskimos and in addition a few of the practises and customs which have an intimate bearing upon their mortuary rites. From the standpoint of pure ethnology and also ethnological archeology the burials, mortuary rites and memorials of the Eskimo people are fundamentally important to the broader and more general subject of Eskimo ethnology.

Since the time of Nelson's and Petrof's investigations among the western Eskimos great changes have taken place in their geographical distribution. The group or tribal boundaries given by Nelson can no longer be applied. Since the Americanization of Alaska began demarcation lines separating these people into tribes have become indistinct. Increased social contacts have caused intertribal and intervillage marriages, so that bloods have been pretty generally mixed. Where the Malmutes, Kuskokwagamutes, Ikogamutes or Nunivagamutes begin or end geographically would be a very difficult matter to determine. For the purpose of this study it is not necessary to make such fine distinctions, since the matter at hand depends to a greater extent upon custom and language grouping. Philologically the western Eskimo of Alaska can be divided into two major groups. The first group involves all Eskimo people inhabiting the western coastal belt—averaging two hundred miles in width—from the Alaska Peninsula to Norton Sound. The second group begins at Norton Sound and involves all Eskimo people living in a similar coastal belt from Norton Sound to Point Barrow. Within these groups can be found dialectic differences which in turn could be used for the basis of finer distinctions, yet they do not affect the custom grouping. This dialectical differentiation rather than customs differentiation was no doubt the basis upon which Nelson constructed his cultural classification.

By grouping the western Eskimos of Alaska according to their mortuary practises and customs we find that, not

unlike the linguistic grouping, two major groups prevail. The line of demarcation between the two major mortuary custom groups is, for this purpose, identical with that of the language groups. However, we must recognize that even this group classification does not imply such differences in individual or group characteristics as to lead the reader to believe that there are sharply defined tribes, such as are found among the American Indians. The death, burial, memorial and religious rites of these people are taken as the basis for grouping them according to their mortuary customs. There is no doubt that these two major mortuary and linguistic groups existed long before the white man established contacts with the western Alaska Eskimos. The line separating these groups is comparatively sharp, while the boundaries of the groups given by Nelson are rather indistinct.

FIG. 1. GRAVE OF AN ESKIMO WOMAN OF KIPNAGAMUTE

HERE STARVING DOGS AND MARAUDING ANIMALS HAVE TORN THE GRAVE BOX OPEN AND HAVE MADE A GOOD MEAL OF THE CORPSE. SIGHTS LIKE THIS ARE COMMON IN THE COASTAL SECTION OF ALASKA BETWEEN THE YUKON AND KUSKOKWIM RIVERS.

Clark M. Garber

CUSTOM AND PHILOLOGICAL DISTRIBUTION OF THE WESTERN ALASKA ESKIMOS. 1932.

And it is difficult to determine where one group began and another stopped, because of the gradual merging of each group with its neighboring groups. In this discussion I will therefore refer to these two groups as the northern and southern groups of western Alaska Eskimos.

In his primitive state the Eskimo devotes his life, not to the accumulation of a large amount of worldly goods and the preparation for death, but to the proposition of making his existence on earth just as pleasant and effortless as possible. Not until he arrives at death's door does he expect to attain happiness. The Eskimo after-life is available to good and bad alike, for in his religion there is no eternal punishment for the wicked or evil. Closely associated with his primitive religion are the customs which he has developed in the matter of preparing the dying and the dead for proper entry into the world of happiness beyond.

Causes of Death

The white man has found an easy way to account for an unaccountable death by laying the cause to complications. To the Eskimo this simple explanation would not suffice. There are many causes of death among primitive peoples. Some they understand because they are visible, but the invisible mysterious deaths are always attributed to the displeasure of the spirits. The Eskimo world is full of spirits. All animate and inanimate things have them. There are spirits of the living and spirits of the dead.

The causes of death may, for the purpose of this discussion, be classed as natural and mysterious or visible and invisible. The natural causes of death are war casualties, domestic quarrels, accidents, conflicts with wild beasts, suicide and old age. The mysterious causes of death are those due to sickness, insanity, childbirth, evil spirits and disappearance.

In the cases of sudden death no preparatory rites could be accomplished. Even in cases of death from old age sudden demise was in ancient days expected. In fact, it was a social custom of economic compulsion, when advanced years brought on the inability to contribute to the support of the household, that the life of the aged should be snuffed out by the knife in the hands of some relative or shamin. This custom was not practised at all times. Years of famine and starvation were the compelling economic cause. Then it became necessary to restrict the consumption of foods to the able-bodied. Male children were also favored in this economic elimination of unnecessary food consumers. All mortuary rites attending sudden death were, of necessity, conducted subsequent to death, *i.e.*, no preliminary preparations could be made.

It was the mysterious causes of death that permitted actual preparations before death. In the case of disease it was believed that the person afflicted had displeased one or more of the spirits. If the magic, incantations and physical ministrations of the shamin or witch doctor failed to effect a cure, then it was decided that the evil spirits infesting the sick person could not be appeased nor could they be forced to leave the body.

FIG. 2. ILLUSTRATING THE METHOD OF INTERMENT ON BERING STRAIT

THE CORPSE HAS BEEN WRAPPED IN A WALRUS HIDE AND THEN PLACED IN A CRUDE COFFIN MADE OF ROUGH HEWN PLANKS. BEFORE THIS GRAVE COULD BE EXPOSED IT WAS NECESSARY TO REMOVE A QUANTITY OF LARGE ROCKS WHICH HAD BEEN PLACED ON TOP OF THE GRAVE AS A PROTECTION AGAINST PREDATORY ANIMALS.

FIG. 3. ABOVE GROUND BURIALS FOUND AT AKOOLARAK ON THE LOWER KUSKOKWIM RIVER. EACH BOX CONTAINS THE CORPSE OF AN ADULT WHICH HAS BEEN JACK-KNIFED IN ORDER THAT IT MAY OCCUPY THIS SMALL SPACE. THE BOXES ARE MADE OF ROUGH HEWN PLANKS FASTENED TOGETHER WITH WOODEN DOWELS AND RAWHIDE LASHINGS.

The patient thereupon stoically resigned himself to his fate and preparations were made for his death. Should the shamin experience too many failures in his practise of medical rites, he was looked upon as a man of evil. This has been the cause of an early death for many a shamin. To-day the western Eskimo is treated for his ills by the white man's *yungchowista* (doctor), yet after fifty years of the white man's educative efforts they have little faith in the white man's medicine. I have witnessed them procure medicines from the white doctor, take this medicine directly to their shamin or *yungchowista,* who destroyed it or kept it for his own purposes, and ask their own conjurer of medicine to treat them for their ills.

The physical ministrations practised on the sick by the shamins very often were, unknown to them, the actual cause of the patient's death. I recall one case of this kind which I personally witnessed. In the village of Keengegan on Bering Strait a small boy had contracted pneumonia. The medicine woman of the village was called in to minister to the patient, contrary to my advice to the parents. After many feelings and manipulations of the child's body this authority on Eskimo medicine announced that the child's liver was very much enlarged. She then proceeded to reduce this enlargement by mechanical force, even against my vehement objections. The result was a serious pulmonary hemorrhage, which caused death in a very short time.

Lingering sickness very often resulted in sudden death. Among the northern Eskimos of western Alaska it was the custom to shorten life in cases of long sickness. This amounted to nothing less than deliberately killing the sick person. The act was usually performed by some close relative and was not committed unless the sick person was a great burden to the relatives. Thus we see an economic situation again dictating who shall live and who shall die. Although I did not witness such an act of mercy and economic adjustment I recall one case in which no doubt could remain in my mind that the act had been done. This was a case of a once famous hunter who had been brought to his bed of reindeer furs suffering from the white man's dreaded plague. For several weeks this man lived with his brother, growing weaker and weaker each day. On this occasion I came into the innie to bring comfort and medicine to the patient. His brother sat near him, whetting his hunting knife to a razor edge. Both knew the purpose of this preparation, yet they visited, conversed about many matters and even joked occasionally, but neither made any allusion to the contemplated act. On the following morning a cousin of the sick man came to me with the advice that the patient had died during the night. Upon my suggestion that I examine the body, consternation was plainly visible

on his face. This convinced me that the contemplated death pact had been carried out. But, since it was in fact an act of mercy and economic adjustment I did not deem it advisable to pry into the affair any further. In truth the confidence of these people would thereby be destroyed and I would gain nothing from their tight-lipped stoicism. The body was then clothed in new reindeer skin parka, new mukluks and new sealskin mittens, all of which had been made in preparation and expectation of this death. The coffin or box was built outside the innie and the body hoisted through the window or smoke hole in the top, after which it was placed in the box and the funeral rites begun.

Death of the Insane: Eskimo people have a great fear of an insane person. They believe that the spirits have all forsaken him and that he just wanders about aimlessly. It is also believed that evil spirits enter the body in which the good spirits will no longer live. For this reason it is thought that the insane person is just the same as dead, but that the spirits have left his body while he was yet alive. Violently insane persons were put to death quickly, since they were believed to be very dangerous. Others less violent were tolerated until a more opportune time or until they had committed some depredation that warranted quick destruction. In a village on the Seward Peninsula a man's brother-in-law had gone insane. This crazy person was tolerated about the innie and was even fed and slept in his brother-in-law's dwelling. However, one night before the household had retired, this insane man became violent and threatened to kill all members of the family after they were all asleep. His brother-in-law waited until the crazy man had fallen asleep in his bunk and then without the least compunction stabbed him to death. His body was then prepared for burial, but he must be buried without the embellishment of new clothing. The good spirits had left his body and would never return. No weapons, tools or implements could be placed in his grave, else he may run amuck and bring unhappiness in the next world.

One day (1926) I was very much surprised to receive the following letter from a man who lived near the Eskimo village of Ikpick.

Dear Garber:

You know my brother he crazy You say alright I shoot him.

Here we find a young man ready to carry out tribal custom long after he had established contact with white missionaries. There can be no doubt that he would have destroyed his insane brother had I but given my sanction to the deed. Fortunately the next traveler

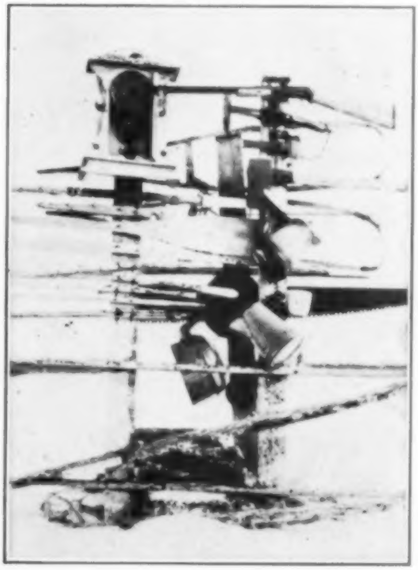


FIG. 4. ESKIMO BURIAL

AT THE VILLAGE OF KINAGAMUTE ON THE LOWER KUSKOKWIM RIVER. THE COFFIN IS PLACED ON THE GROUND BETWEEN THE POSTS WHICH SUPPORT THE PROPERTY OF THE DECEASED. NOTE THE MIXTURE OF PRIMITIVE WEAPONS AND TOOLS WITH THE MODERN ONES OF THE WHITE MAN'S MANUFACTURE.

FIG. 5. PORTION OF ESKIMO CEMETERY AT KEENGEGAN ON BERING STRAIT
HERE WE FIND THE GRAVES PLACED AMONG THE ROCKS ON THE MOUNTAIN SIDE. THE TOOLS, HUNTING GEAR, UMIAK AND KAIYAK FRAMES AND SOME TROPHIES OF THE HUNT HAVE BEEN STREWN ABOUT AND OVER THE BURIALS. IN THIS CEMETERY THE AUTHOR COUNTED MORE THAN EIGHTEEN HUNDRED VISIBLE BURIALS, WHICH ATTESTS THE STRENGTH AND SIZE ONCE ATTAINED BY THIS COLONY. INHUMATIONS WHICH HAVE DISAPPEARED FROM SIGHT BENEATH THE TUNDRA WOULD PROBABLY NUMBER INTO THE THOUSANDS.

brought word that the insane man had died a natural death during an insane fit. *Did he?*

If a person designates before his death just where he wishes his body to rest it is considered a very sacred duty on the part of the relatives to see that the dead man's wishes are complied with. Some have selected crevices in the mountain rocks, some designate the tops of peaks, some wish a particular plot of ground which has attracted them, and some choose to have their bodies rest in old family innies which are no longer used as dwellings. It is rather infrequent that the Eskimo selects his burial spot before death. The usual custom is to leave the matter for the relatives to decide. This results in the body being buried in the common burial ground.

Burial Rites

Among all the western Alaska Eskimos it is customary to remove the corpse from the innie on the same day that death occurs. If death occurs at night the body is removed from the dwelling at daybreak. In some instances, particularly to the south of Norton Sound, I have known the body to be kept until the second day after death before inhumation. This, however, is an exception rather than the rule. It is only under unusual circumstances that a corpse is kept over night. Such circumstances involve the making of the box, sending word to relatives or completing the new outfit of clothing for the corpse. The corpse is never taken out of the dwelling through the common entrance. In the case of an innie it is removed through the smoke hole or window in the top of the structure. If the deceased lived in a log cabin or other frame structure above ground the corpse is taken out through the window or a special hole is made in the roof for the purpose. Death in a snow igloo presents another problem, since there are no windows in this type of dwelling. In this case a couple of blocks of snow are removed from the wall near the ground and the corpse taken out through the resulting opening.

Death is usually attended by relatives and friends, who crowd into the small dwelling in such numbers that there is little space left for the dead or dying person. Mourning continues until the body is removed from the dwelling. This consists in loud wailing and moaning on the part of the relatives, but no tears of sorrow are shed. The reason why tears are not shed as a matter of sorrowful mourning for the dead is a religious one. After an Eskimo being has departed this world and comes into the next he must, before he can enter into the place of everlasting happiness, cross a river of tears. If relatives and friends of the dead shed tears of sorrow this river of tears will be swollen to such an extent that the dead person's spirit will be unable to cross and will wander about until the flood of tears subsides. The funeral rites of the western Eskimos are therefore seldom attended by the shedding of tears of sorrow. I have witnessed parents bury their children and children bury their parents without the least demonstration in the way of tears.

Among the western Alaska Eskimos to the south of Norton Sound there has developed a very peculiar and interesting custom of preparing the corpse for inhumation. This involves bringing the body into a jack-knifed position by drawing the knees up to the shoulders and placing the hands and forearms across the abdomen. The head is then forced down so that it rests upon the knees. In this position the corpse is wrapped in its death shroud, consisting of reindeer or sealskins and is then bound tightly with rawhide lashings. When the body has cooled and the muscles have hardened the lashings are removed and the body introduced into the box that has been built for it. Relatives are not allowed to prepare the corpse for burial, unless it be an extreme circumstance that makes such action necessary. The box is made by the men of the village, and in case the corpse is a male the men of the village dress it for burial. Up to the time of this writing the author has not succeeded in his efforts to determine the factors responsible for the development of this peculiar type of burial. One of several factors or even a combination of these factors may be the underlying cause. Of these religion, economics, social custom and supersti-

FIG. 6. ESKIMO BURIALS AT TANUNAK ON NELSON ISLAND

THE GRAVES BEARING POTS, KETTLES, BUCKETS, PANS, LADLES, ETC., ARE THOSE OF WOMEN AND ARE NOT HARD TO DISTINGUISH FROM THE GRAVES OF MEN, WHICH BEAR WEAPONS, HUNTING EQUIPMENT, TRAIL EQUIPMENT, SLEDS AND TOOLS.

tious fears may be mentioned. If the jack-knife burial could be attributed to any of these factors we would yet have to find the reason. Underlying any primitive custom there is a reason for its development. This reason may be lost in antiquity, so that the Eskimo of to-day would know no more about it than the ethnologist himself.

In the coastal section to the south of Norton Sound driftwood has frequently been so scarce that there has not been sufficient to provide material for the making of coffins. In this case the jack-knifed corpse is simply placed in a sitting position leaning against a stake placed at its back. Here the corpse is left to sit on the tundra, where it may furnish many good meals for the starving dogs and predatory animals. In some cases I have observed these tundra burials entirely exposed, with the exception of a few stakes driven into the ground around them or some of the deceased's implements scattered over them. Of course this arrangement affords no effective barrier to wolves or starving dogs. Even the wooden coffins have at times been clawed and chewed apart in order that savage animal hunger may be satisfied. Fig. 1 illustrates the grave of a woman which has been ravaged in this manner.

North of Norton Sound we find the preparations of the body for burial very similar to those used by the Eskimos to the south. However, there is one great difference in the preparations of the dead for burial between these two groups of western Eskimos. The Eskimos in the northern section do not jack-knife the corpse for burial. Here the body is dressed in new fur clothing and wrapped in a walrus hide or reindeer skin. Then it is laid at full length upon a rough hewn plank. This plank supporting the body is then carried or hauled to the burial grounds where it is deposited upon the ground—sometimes a niche is formed with loose rocks for this purpose—with the feet to the east in order that the departing spirit may face the rising sun (Fig. 4). A plank is then placed on each side of the corpse and another over the top, thus forming a long rectangular box with open ends. In some cases these open ends have been fitted with end boards fastened in with dowels and lashings. In others large flat stones have been placed over the ends. The grave is now covered over with rocks to prevent marauding animals from getting at the corpse. On Bering Strait I have found graves made of shallow stone walls, in which the corpse was placed without the protection of a wooden coffin. In this case large flat rocks were placed across the walls as a covering or lid and then a mound of loose rocks built over the entire grave. This method of interment was probably developed much earlier than the coffin method.

Near the village of Tanunak on Nelson Island the author discovered two different types of graves, leading to the belief that two separate peoples had established contact at this place. Investigation of the matter has brought to light the information that a group or hunting party of Innuit landed on this island many years ago and established a colony here in close proximity to the Yuits, who were the native inhabitants of the island. Examination of the graves of these people and their contents in the way of implements and ornaments revealed a very close association or resemblance to the Bering Strait or St. Lawrence Island Eskimo type of burial. Here was found the full length burial of the Seward Peninsula and Kotzebue Sound Eskimos closely associated with the jack-knife burial characteristic of the Nunivak and Nelson Island Eskimos. Further investigation disclosed that a strange people were apparently lost in a storm at sea and were driven ashore on this island. Not knowing where they were or how to return to

their own people they established a colony near the present village of Tanunak. These people called themselves Innuit, which is the Eskimo term for "the people" of Bering Strait. They could not converse with the native Eskimos of Nelson Island and consequently mingled but little with other peoples. Eventually the colony died out, and now all that is visible are some of the graves and the old village site.

Should an Eskimo person die while living in a temporary camp or summer colony away from the main village his body is not taken to the main village for burial. His grave is prepared right at the camp and often within a few feet of the innie or tent. For this reason the entire western coast of Alaska and the shores of the lakes and streams will be found dotted promiscuously with burials.

The practise or custom of burying the dead in wooden boxes has no doubt had its beginning in the proximity of the Alaska Peninsula. A study of the burial customs and methods of the western Alaska Eskimos reveals a gradual dwindling of this practise as we follow the western coast of Alaska from south to north, and when we arrive as far north as Bering Strait or Kotzebue Sound we find that it is only within comparatively recent years that wooden coffins have been made for the dead. Even now among the northern Eskimos of Alaska we may find an occasional exposed burial, *i.e.*, burial without a coffin, particularly where driftwood is short or absent and there is nothing from which to make the box.

Closely associated with their primitive religion the western Eskimos have developed certain burial rites and definite procedures involving the burial of the dead and the respective behavior of the living thereafter. Those living to the south of Norton Sound believe that the spirit of the male dead remains with the body for a period of five days. For the females this period is four days. Subsequently, the spirit leaves the body and wanders at will, returning to the body if it so desires or immediately crosses the river of tears into the land of happiness. During this five- or four-day period no person is allowed to do any work with sharp edge tools, because the

FIG. 7. OLD BURIALS AT THE VILLAGE OF QUIGILLINGOK

COMPARE THESE GRAVES WITH THE ONE ILLUSTRATED IN FIG. 8, WHICH IS A MORE RECENT BURIAL IN THE SAME VILLAGE.

FIG. 8. A WOMAN'S GRAVE
IN THE VILLAGE OF QUIGILLINGOK. THIS BURIAL IS ESTIMATED TO BE MORE THAN ONE HUNDRED YEARS LATER THAN THOSE IN FIG. 7. REGARDLESS OF THIS APPARENT DIFFERENCE, THE BURIAL CUSTOMS AND RITES HAVE REMAINED VIRTUALLY THE SAME.

spirit of the dead person may be hovering close and consequently be injured. For a period of one day after death occurs none of the relatives of the deceased are permitted to do any work at all. They must just lounge around the innie and keep busy at doing nothing. To the north of Norton Sound the same periods of abstinence are observed, but there the time involved is five days for the male and three for the female. Although this period of abstinence may vary considerably throughout the area covered by this discussion it is fundamental that the custom of observing them prevails among all western Alaska Eskimos. In some villages certain foods may not be eaten by the relatives of the dead during this period of abstinence. These foods in particular were those for which the deceased had a special fondness.

Transportation of the dead must be accomplished after the dictates of custom and taboos. On the Kuskokwim River a corpse can not be transported on the river, either by boat or by sled. To desecrate this custom would incur the wrath of the fish spirits, and as a result the fish would not come into the river the following season. This is a general taboo among all the villages to the south of Norton Sound. Should a person drown, his body must be recovered, else there will be no run of fish the next summer. With the northern group of Eskimos, particularly in the Bering Strait villages, the dead must not be transported to the burial ground in a roundabout way. The corpse must be taken over the shortest route possible between the death house and the grave.

It has been a common custom among all western Eskimos to make offerings of food to the spirit of the dead. This is done immediately after the body has been placed in its grave. The food offerings consist in choice morsels of all foods common to the particular locality in which the deceased has lived. Seal meat, walrus meat, reindeer meat, muktuk, dried fish, clams, berries and other choice dishes may be offered to the spirit of the dead. These offerings are made only by the surviving relatives of the deceased. In some localities it is the practise for the relatives to carry the food offerings to the burial place and after placing generous portions on the grave they would assemble about the grave and feast with the spirit of the departed.

Types of Graves

On the lower Yukon River, about Norton Sound and on the lower Kuskokwim River, it is a common thing to see some of the graves built above ground. What belief or superstition gave rise to this special type of grave will probably never be known, but was possibly done to protect the corpse from marauding animals. Inquiries made

among the old men, shamins and witch doctors of the villages fail to throw any light whatever upon the origin of this type of burial. The coffin or box is generally supported by a framework of posts, which are notched in the top to support cross pieces. However, in a few instances I have observed the stumps of trees used for this purpose. In this case the trunk portion of the stump is placed in the ground and the roots are above ground. The roots are then cut down to make a tablelike structure on which the coffin is placed (Fig. 3). The coffin is made of hewn planks fastened together by dowels and rawhide lashings. In the box with the corpse were placed all the small trinkets, extra ornaments, tools and weapons of the deceased. In the case of a woman the box contained her sewing kit, skinning and tanning implements and any other small articles which may have become a part of her household functions. Her beads, ear rings, bracelets and other ornaments adorned her body, having been placed there at the time of death. All the property of a movable nature belonging to men, women or children was placed within or upon their respective graves. It is only in cases where the deceased has been insane, an evil person, has died from some loathsome disease, is stillborn or has accumulated very little property that the graves are devoid of these objects.

The placing of the deceased person's property in and on his grave has a close association with the religious philosophy of the Eskimo. As mentioned in a former paragraph, all things have spirits; hence, when a man dies, especially his hunting gear, camping equipment and tools must accompany him to the grave in order that his spirit, on entering the world of happiness, may be helped by the spirit of the rifle, harpoon, spear, kaiyak, umiak, sled, knives, etc. Therefore we find as illustrated in Figs. 4, 5 and 6 all the movable property of the

FIG. 9. MEMORIAL FIGURE

PLACED OVER A WOMAN'S GRAVE AT THE VILLAGE OF KINAGAMUTE. NELSON HEARD ABOUT THESE MEMORIALS AT THE TIME OF HIS ETHNOLOGICAL WORK AMONG THE WESTERN ESKIMOS BUT NEVER HAD THE OPPORTUNITY TO INVESTIGATE AND EXAMINE THEM.

deceased placed upon his grave. In some cases I have found small objects, such as stone knife blades, adze blades, spear and harpoon points and much ivory buried beneath the coffin. Some are placed within the box, while some, especially the larger objects, are strewn about over the top of the grave. This is the custom with the Eskimos north of Norton Sound. The Eskimos south of Norton Sound place the coffin on the ground and on each side of it set a post in the ground. In some cases only a single post is used. Upon these posts are fastened the various items belonging to the deceased.

Near the village of Quigillingok at the mouth of the Kuskokwim River are found two different types of burials. The difference in these burials does not imply a change in custom between the

FIG. 10. GROUP OF ESKIMO GRAVES AT KINAGAMUTE ON THE LOWER KUSKOKWIM RIVER. THESE ARE MEMORIAL FIGURES CARVED BY RELATIVES OF THE DECEASED.

times of the two interments. It portrays a change in the economic factors controlling burials at these two times (Figs. 7 and 8). The graves made of rough logs represent burials which are estimated to be more than a hundred years older than the other in which the white man's cut lumber has been used. In both burials the corpse has been jackknifed before interment and the property of the deceased has been placed within and upon the graves in the customary manner. Making the box from the white man's cut lumber has proven to be both a labor-saving and time-saving proposition and yet effects the inhumation in strict accord with customs which have prevailed for many generations. Fig. 7 illustrates a grave in which the coffin is made of logs split in half and mortised at the corners. The flat sides of these hewn slabs form the inner surfaces of the box.

At the village of Kinagamute on the

FIG. 11. MEMORIAL FIGURES ERECTED OVER NATIVE GRAVES AT THE VILLAGE OF NUNACHAGAMUTE

lower Kuskokwim River we find a peculiar and most interesting type of burial. At no other place among the Western Eskimos of Alaska do we find memorial grave markers such as these. Two posts are set at the head of the grave about three feet apart and extending to a height of six feet above the ground. Beginning about thirty inches from the ground the two posts are boarded up to within one foot of the tie beam which joins the posts across the top. At the top of the boarded section there extends a roof or canopy for about two feet at right angle to the upper margin of the boarded surface. Under this canopy and fastened to the boarded surface is found a human figure. The head is carved from wood and is made in an oval shape with ivory or bone insets for eyes and mouth. The hands are also of wood and frequently hold some object, such as a spoon, knife, sewing kit, etc. The torso is covered by fur or cloth garments, adorned with pendants, buttons, etc. This is, in all probability, the type of burial mentioned by Nelson in the Eighteenth Report of the Bureau of Ethnology in which he states, "I was informed that the graveyards of the villages on the Kuskokwim, below Kolmakof Redoubt, are full of remarkable images of carved wood. One was described to me as being roofed with wooden slabs and consisted of a life-size figure, with round face, narrow slits for eyes, and four hands like a Hindoo Idol" (Figs. 9 and 10).

At Nunachagamute, a village located in the flat tundrous country between the Yukon and Kuskokwim Rivers, will be found burials very similar to that described in the preceding paragraph. In these burials not all the figures are mounted on the canopied frame (Fig. 11). The two figures with outstretched arms have their base or support in the ground. The figure at the right is adorned with a bead necklace, supports in one hand an ivory snow knife and in the other hand a modern kitchen knife. These wooden figures are not intended to portray the physiognomy of the deceased person. They are made as me-

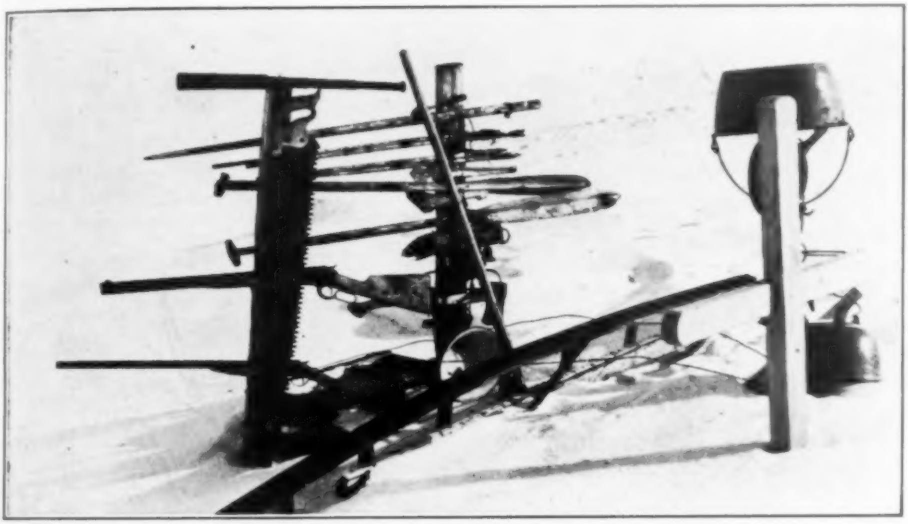


FIG. 12. TYPICAL BURIAL OF THE ESKIMOS SOUTH OF NORTON SOUND

THE MIXTURE OF NATIVE AND WHITE MAN'S IMPLEMENTS MARKS THE TRANSITION OF THE ESKIMO FROM THE PRIMITIVE TO THE SEMI-CIVILIZED STATE. A BURIAL OF THIS KIND REPRESENTS A CONSIDERABLE ECONOMIC LOSS TO THE CHILDREN OF THE DECEASED.

FIG. 13. TYPICAL BURIAL OF THE WESTERN ESKIMO NORTH OF NORTON SOUND

THIS IS THE GRAVE OF A FAMOUS HUNTER. HIS SEPULCHER IS STREWN WITH TROPHIES OF THE HUNT AND ALL HIS PROPERTY.

morials to the dead and have the same purport as one of the white man's tombstones. The carving is done by relatives of the dead. It is not always done immediately after death, but may be done at any time. One instance has come to my attention in which one figure was carved by the husband of a deceased woman. This figure was mounted over the grave shortly after inhumation. About fifteen years later the little son of this man and wife had grown up and desired to erect a memorial to his mother. He therefore carved his own memorial figure and placed it upon his mother's grave along with that of his father.

In the typical Yukon-Kuskokwim burial we find posts erected beside the grave, and on these are placed all items of property which belonged to the deceased. This typical burial is well illustrated in Fig. 12. A mingling of Eskimo and white man products is visible. The coffin, which rests on the ground between the posts, is almost covered with snow. It may be interesting to the reader to know that this grave bears more than four hundred dollars worth of guns, tools and other wares figured at prevailing Alaska prices. The white cross indicates that the man's wife or daughter has come under the influence of the missionaries, yet this influence was apparently not strong enough to overcome the customs of past generations. Perhaps the white man's religion is not right, so they think that the pots, kettles and pans had better be put on the grave to make sure that the spirit of the dead will not want in the next world.

Let us now examine a typical grave of the northern group of western Eskimos (Fig. 13). This is the grave of a famous and once powerful hunter. His trophies adorn his sepulcher. The shoulder blades of two large and one small whale and nine polar bear skulls are visible to attest the prowess of this departed chieftain. His umiak and kaiyak frames are scattered over the grave. His hunting equipment, weapons, tool kit and many other items of his

property are found beneath the stony coffin. This grave is located near the village of Keengegan on Bering Strait. Surely his fame and power will continue with his spirit into the next world. There the spirits of the weapons he has used and the animals he has slain will help him to attain eternal happiness.

Influence of Religion

In recent years the influence of religious workers among the western Alaska Eskimos has had a decided effect upon the mortuary rites and practises of these people. No less than eight religious organizations are represented by missionaries among the western Eskimos. Of these the Greek or Russian Orthodox church has probably had a longer and more lasting influence. But since the Americanization of Alaska began and since the Russian church no longer supports a paid clergy in Alaska, there is a perceptible weakening of the Russian Orthodox influence. On the lower Yukon and Kuskokwim Rivers will be found Russian Orthodox churches maintained by the Eskimo people and presided over by Eskimo priests (Figs. 14 and 15). With the coming of the white man's religion the Eskimos are slowly but surely being weaned away from their racial mortuary customs. Those who have succumbed to the new religious influence will be buried underground, and the cross of the Orthodox or Christian church will appear as their only grave memorial. The white man's religion has not reached all the western Eskimos. In some of the isolated sections they will be found, not only living in their primitive state, but practising the customs of their forefathers. Among these remaining primitive settlements of Eskimos the ethnologist, anthropologist and archeologist may still find a virgin field for their endeavors.

Group Burials

The proposition of burying a number of people in a common grave has never been adopted as a general practise or custom among the Eskimos. There are, however, in the Bering Strait region some cases in which this system of burial has been utilized. On the top of

FIG. 14. RUSSIAN ORTHODOX CHURCH AT THE VILLAGE OF QUITHLUK ON THE LOWER KUSKOKWIM RIVER. THIS CHURCH STANDS IN A SETTLEMENT SURROUNDED BY MISSIONARIES OF THE CHRISTIAN RELIGION, YET ITS FOLLOWERS CLING FAITHFULLY TO THE RELIGION GIVEN THEM BY THE RUSSIANS.

FIG. 15. RUSSIAN ORTHODOX CHURCH AT RUSSIAN MISSION
ON THE LOWER YUKON RIVER. BUILT MANY YEARS PRIOR TO THE PURCHASE OF ALASKA BY THE UNITED STATES, THIS CHURCH REPRESENTS ONE OF THE MOST INTERESTING RELICS OF RUSSIAN DAYS IN ALASKA. RUSSIAN MISSION WAS AT ONE TIME A STRONG RUSSIAN POST SITUATED ON THE OLD OVERLAND TRAIL FROM ST. MICHAEL TO ILIAMNA BAY. SINCE THEN THE ESKIMO PEOPLE HAVE DECREASED IN NUMBERS UNTIL HARDLY ENOUGH NOW REMAIN TO CONDUCT THE ORTHODOX SERVICES IN THE OLD CHURCH.

a mountain ridge back of the village of Keengegan I have observed (1926) several large rock mounds which were approximately twenty feet in diameter. The rocks in these mounds were rather uniform in size, none of them being larger than one man could carry. This fact led me to some speculation as to the contents of the mound and how it may have originated. Believing that there may be some special type of burial hidden beneath these piles of rock I decided to investigate them thoroughly. The results more than justified the many hours of labor, for in the bottom of the first mound excavated were found five skeletons. Now before disturbing these remains a peculiar situation was observed regarding the burial. The bodies had been placed in the grave, not in parallel arrangement, as one would suspect, but in a haphazard pile. Examination of the skeletal remains disclosed the fact that they were warrior dead. In two of them flint arrow points were wedged between the rib bones and in another the skull had been punctured by a bullet which yet remained within the cranium. From this grave much war material was collected for further study. Later it was learned from the old men of the nearby village that these rock mounds contained the bodies of enemy warriors who had been killed in battle. This, no doubt, accounts for the disrespect accorded them by burying them in a haphazard heap. This is the only deliberate group burial which I have been able to locate in all the Eskimo burials which it has been my privilege to examine. However, I am informed by the Eskimo people that such burials also exist at East Cape, Siberia, and on Diomede and King Islands.

There is another type of group burial which may be classed as an involuntary

group inhumation. These may also be called epidemic group burials. The Eskimo population of Alaska has suffered much on account of famines, epidemics of smallpox, measles, influenza and other contagious diseases, until at the present time the actual Eskimo population of Alaska is only about one fourth the population of pre-Russian days. Epidemics caused deaths by the wholesale. Whole families and even entire colonies were wiped out. Many times families were trapped in their innies by these epidemics and there they perished. Fig. 16 shows the site of an Eskimo village near Cape Prince of Wales. This village of more than sixty people was entirely wiped out by the influenza epidemic of 1918. When death came no friends or relatives remained to care for the bodies of the dead. Their underground dwelling or innie became their grave. As years pass by these innies decay, the sod roof falls in, and an effectual underground group inhumation is produced.

Archeological Importance

The archeologist will find Eskimo burials equally as important as village ruins. While village sites and remains will be visible for a much longer time, the Eskimo grave contains a much greater store of archeological and cultural treasures. By reason of the fact that Eskimo burials of the past were surface burials their disintegration takes place very rapidly. Soon the tundra vegetation has covered them entirely, so that they may be virtually lost for all time. Occasionally these old burials may be identified by small mounds. Sometimes small pieces of hand-worked wood may be found on the surface, indicating that burials may be found nearby. The burials and village sites which fall within the memories of the present generation of Eskimos are of little value to the archeologist, who is interested in ancient cultures. But, to the ethnological archeologist these burials, even though they are no more than one hundred years old, hold a vast store of ma-

FIG. 16. POOLUZOK, AN ESKIMO VILLAGE ON BERING STRAIT

THIS COLONY, WHICH NUMBERED MORE THAN SIXTY PEOPLE, WAS ENTIRELY WIPED OUT BY THE INFLUENZA EPIDEMIC OF 1918. WHOLE FAMILIES ARE BURIED WITHIN THEIR INNIES, WHICH HAVE CAVED IN BY DECAY.

terials and valuable information. The author has frequently discovered such old and forgotten sites through the legends and stories of the Eskimo people. Had we some means of discovering burials and village sites of a thousand years ago, yes, two thousand years ago, then our cultural determination of Eskimo sources and racial history would be greatly facilitated.

Eskimo burials and ruins which lie within the frequented lanes of travel are now being stripped of their archeological specimens by curio seekers, who do not appreciate the value of sequence and association in the collection of this valuable material. True, much of it reaches our museums, but even there its status can be nothing more than an Eskimo curio collection. Eskimos are thereby encouraged to make these excavations and sell the specimens which they find to the traveling public. Fortunately, their superstitious fears of the shades of the dead keep them from destroying their burials, and they feel that the white man who will face the wrath of the spirits to acquire curios from the graves is indeed a brave man. Of course, the ethnologist may draw many inferences from a collection of Eskimo curios which would supply him with indirect evidence concerning the manufacture and use of the various instruments and may even infer certain things to be true about the people who made and used them. So many erroneous conclusions have been drawn from such miscellaneous collections that I have come to favor direct evidence and information as the only reliable method of determining the facts about native peoples who are still existing. One year of life in intimate contact with a primitive people is worth more than ten years of perusing a conglomerate collection of curios, in so far as accurate ethnological data are concerned.

THE EXPLORATION OF THE FREE ATMOSPHERE

By LOUIS P. HARRISON
U. S. WEATHER BUREAU

The first and almost unheralded ascent of Professor Auguste Piccard in a balloon to a height of about 15,780 meters (51,770 ft.) on May 27, 1931, broke upon an astonished world and brought to the attention of the public the mysterious stratosphere. Since that time not less than five similar ascents have been made, with new and greater ones projected for the future. While the results of these aerial voyages high into the atmosphere disclosed much that was new, especially for the student of cosmic rays, the major results ascertained had long been known to the meteorologist, thanks to the means evolved more than a quarter of a century ago. It is therefore well to indicate at this time the early history and development of the principal methods hitherto employed for the exploration of the free atmosphere, the more important facts regarding our airy medium which these methods revealed and finally the prospects for new advances which the future holds in store for the science of meteorology.

Early History and Development

The first really important advance in the study of the upper atmosphere was the result of the famous experiment conducted on September 19, 1648, by Pascal's brother-in-law, Perier, who carried a Torricellian tube to an elevation of 1,460 meters (4,790 ft.) up the Puy de Dôme, one of the highest mountains in Auvergne, for it proved conclusively that the pressure of the atmosphere decreases as one ascends in it, and hence that it must be regarded as a fluid having weight and an upper limit.

The next important step in this field was not possible until after the thermometer, devised originally about 1597 by Galileo in the form of a thermoscope, had been brought to a form which gave comparable readings. This occurred during the period approximately between 1650 and 1750, so that following the middle of the seventeenth century it was not uncommon for expeditions led by scientific philosophers in various parts of the world to make ascents of the mountains for the purpose of observing the change of the barometer and the temperature of the air with height.

Toward the end of the eighteenth century, especially following the publication of the masterly "*Essai sur l'hygrometrie*" by the Swiss geologist and physicist, de Saussure, in 1783, observations of the relative humidity were also made on these expeditions, usually employing for this purpose a hygrometer made of specially prepared hair which increased in length with increase in humidity and *vice versa*.

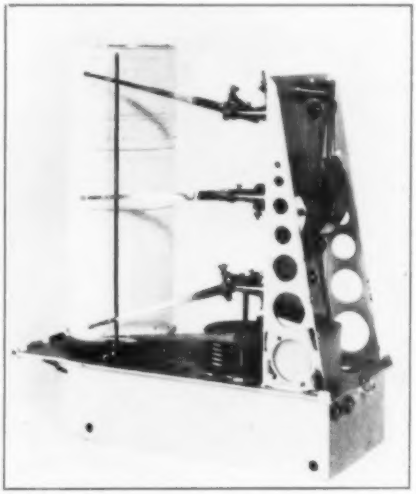
Thus by the close of the first third of the nineteenth century, the mountain observations of such men as Bouguer, H. B. de Saussure, Deluc, Humboldt, the great traveler and naturalist, and others, had shown that the temperature of the air fell with height, on the average, at a rate of about 1° C. per 185 meters, (0.3° F. per 100 ft.), varying with season, time of day, etc. The observations also showed that the moisture content of the air diminished with

height, while samples of air taken at various heights had shown that the concentrations of the other known constituents of the air were essentially constant. Furthermore the law in accordance with which barometric pressure must fall with height and also the correct means for measuring heights in the atmosphere from barometer and temperature observations became known after the publication by Laplace of his great work, "Mécanique Céleste." Finally it was also known that winds generally increase with height and that there were ascending and descending currents in the atmosphere, partly from the study of clouds, which was especially stimulated through the scientific classification thereof by Luke Howard in 1803. However, the information we have just outlined formed nearly the entire store of enlightenment on the subject of the upper air available in the period in question, and moreover had the limitation that it was largely based on mountain observations which did not extend to great heights and were not wholly representative of conditions in the free air.

LAUNCHING A SOUNDING BALLOON

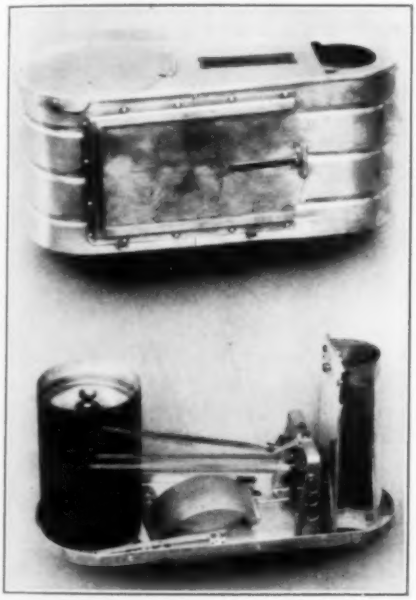
New and more potent methods of investigation had in the meanwhile been developed, for on June 5, 1783, the brothers Montgolfier at Annonay near Lyon in France launched their first free balloon in public, using hot air to give the necessary buoyancy, while by November 21 of that year Pilâtre de Rozier and the Marquis d'Arlandes were carried aloft in a free hot-air balloon and, on December 1, the physicist Charles, accompanied by one of the brothers Robert, who had constructed the envelope, ascended in a hydrogen-filled balloon near Paris to a height of about 2,000 feet, remaining in the air for

about two hours. The latter took with them a thermometer to measure the temperature of the air and a barometer to measure the height. A second flight made on the same day by Charles alone reached an elevation of nearly 9,000 feet. The first scientific balloon ascent was made from London on November 30, 1784, by Dr. John Jeffries, a native of Boston, Massachusetts, living in England. He carried with him a barometer, a thermometer, a hygrometer, an electrometer, a mariner's compass and six glass-stoppered bottles filled with distilled water. The bottles were emptied at various heights and sealed; and the samples of air thus obtained were later analyzed by Cavendish.



SIDE VIEW OF THE FRIEZ TYPE AERO-METEOROGRAPH

WITH PROTECTIVE COVER REMOVED. AN INSTRUMENT CARRIED ON WEATHER BUREAU OBSERVATION AIRPLANES TO MEASURE AND RECORD THE TEMPERATURE, RELATIVE HUMIDITY AND BAROMETRIC PRESSURE OF THE AIR. ON THE LEFT IS THE CYLINDRICAL DRUM WHICH ROTATES BY CLOCKWORK AND CARRIES A SHEET ON WHICH THE THREE PENS TRACE RECORDS OF THE DESIRED DATA. NEAR THE LOWER CENTER IS THE SYLPHON ELEMENT, AN EVACUATED BOX WHOSE EXPANSION WITH DECREASE IN ATMOSPHERIC PRESSURE PERMITS THE MEASUREMENT OF THE BAROMETRIC PRESSURE. NEAR THE RIGHT CENTER IS THE CURVED BIMETALLIC ELEMENT FOR MEASURING THE TEMPERATURE, AND BESIDE IT TO THE LEFT MAY BE SEEN SEVERAL STRANDS OF HUMAN HAIR WHOSE CHANGES IN LENGTH WITH MOISTURE IN THE AIR RECORD THE RELATIVE HUMIDITY.



SOUNDING BALLOON METEOROGRAPH

OF THE FERGUSSON PATTERN, USED IN THE UNITED STATES; AN INSTRUMENT WEIGHING ONLY 200 GRAMS (0.44 LB.) AND DESIGNED TO GIVE A CONTINUOUS RECORD OF THE BAROMETRIC PRESSURE, TEMPERATURE AND RELATIVE HUMIDITY OF THE FREE AIR WHEN CARRIED ALOFT BY A SOUNDING BALLOON. *Below:* INSTRUMENT PROPER SHOWING SMOKED-ALUMINUM RECORD SHEET ON LEFT. *Above:* ALUMINUM PROTECTIVE COVER FOR INSTRUMENT.

In 1803–4, a Belgian physicist, Robertson, made three ascents from Hamburg and St. Petersburg, the latter of which was made under the auspices of the Russian Academy with the object of determining the change in the rate of evaporation of fluids, change of magnetic force and magnetic inclination, and the increase of solar heat with increase in elevation. After some doubt was cast on

VIEW OF AIRPLANE

READY TO MAKE A METEOROLOGICAL SOUNDING TO A HEIGHT OF 17,000 FEET. THE AEROMETEOROGRAPH IS SEEN MOUNTED IN A FRAME ATTACHED TO ONE OF THE STRUTS BETWEEN THE WINGS.

Robertson's results, funds placed at the disposal of the French Academy of Sciences by the French Government were employed upon the proposal of Laplace to finance further balloon ascents. Two ascents were thus made from Paris, one on August 24, 1804, by Biot and Gay-Lussac to a height of 13,000 feet, and the other on September 16, 1804, by Gay-Lussac alone to a height of 23,000 feet. Samples of air were brought down, and later analysis showed the same concentration of gases as observed at the surface, except for water vapor, which was less. The variation of magnetic force with height was also studied.

Scientific ballooning seems to have largely languished for a number of years following this; however, we may take notice of the two ascents made by the Astronomer E. S. Rush with the famous aeronaut Green in September, 1838, and September, 1839, the latter of which reached an altitude of about 25,900 feet. In 1850 there was a revival of interest when J. A. Bixio and J. A. Barral made two ascents.

In 1852, Mr. John Welsh, of Kew Observatory, made a series of four ascents under the auspices of the British Association for the Advancement of Science. The maximum altitude he reached was 22,930 feet. Samples of air were collected, the changes of temperature and humidity observed and the light from clouds examined for polarization. Welsh was the first to inclose his wet- and dry-bulb thermometers (psychrometer) in a polished metal tube through which air was forced by bellows, in order to remove the vitiating effect of the sun, car and observers, on exposed thermometers, and his careful work and discussion of

results were models to be sought after in later years.

In 1858 the British Association again took up the project of scientific ballooning. Various difficulties prevented progress until the year 1862, when James Glaisher of Kew Observatory began his famous series of 28 ascents, which extended to the year 1866. The objects of the observations made concerned primarily the condition of the air in regard to temperature and humidity, and secondarily: (1) Comparison of various instruments for measuring humidity; (2) comparisons of the readings of an aneroid with a mercurial barometer; (3) examination of the electrical condition of the air at different heights; (4) determination of ozone by means of "ozone papers"; (5) determination of variation with height of the horizontal intensity of the earth's magnetism; (6) comparison of the solar spectrum at various heights and times of day; (7) collection of air at different elevations; (8) observation of height, kind, density and thickness of clouds; (9) determination of rate and direction of different currents; (10) observations on sound; (11) observations of solar radiation at different heights; (12) determination of the actinic effects of the sun at different elevations by means of Herschel's actinometer; (13) observation of atmospherical phenomena in general. Glaisher concluded that the thermometers, whether or not ventilated in a polished tube, as Welsh had done, gave the same results. This was later proved to be due to the fact that the instruments were carried either in the car or just beside it, and hence that the temperature and humidity readings were somewhat spurious.

However, valuable results were secured, and one can not help but admire the fortitude with which this investigator and his aeronaut Coxwell bore the discomforts of cold and "altitude sickness" brought about by the high ascents. On the ascent made from Wolverhampton, on September 5, 1862, Coxwell had mounted the ring above the car to disentangle the valve-line while at an altitude of 29,000 feet (barometer 9.75 inches) and the balloon was still ascending. Glaisher in the meanwhile observed that he could not see the hands of the watch nor mercury in the thermometer. Laying his arm on the table he found himself powerless to move it, and then his other arm became similarly affected. His head fell over on his left shoulder and soon he found himself unable to move his legs, back and neck. He fell into a state of insensibility and was finally aroused after several minutes by Coxwell, who in climbing the ring had frozen his hands, and feeling himself becoming senseless and noting Glaisher's condition, was forced to seize the valve cord with his teeth and dip his head two or three times in order to cause the balloon to descend. The maximum altitude reached was later estimated by Professor Assmann of Berlin to be about 27,500 feet. No inconvenience followed Glaisher's insensibility.

A series of balloon ascents in France by C. Flammarion, W. de Fonvielle and G. Tissandier, respectively, at various times during the period 1867–1875 did not end so happily, for on the ascent made from Paris on April 15, 1875, by Tissandier, H. T. Sivel and J. E. Crocé-Spinelli to a height of about 28,000 feet, the latter two were asphyxiated due to the rarefied air, while Tissandier was unconscious about two hours and the balloon fell to earth four and a half hours after the ascent. This unfortunate occurrence caused the cessation of high-altitude scientific ballooning for some years.

It is an interesting commentary on the history of scientific ballooning that a war was the indirect cause of its ultimate revival. It is not often remembered that during the Franco-Prussian war of

1870–71, when Paris was besieged by the Germans and it was impossible to communicate with the outside world from that city by ordinary means, the French Government established two factories for the manufacture of balloons, which were principally used to carry despatches to the unbeleaguered territory of the country. Thus a total of 61 balloons left Paris during the period from September 23, 1870, to January 28, 1871, carrying about 153 people and a total of about 2,500,000 letters, also with a number of carrier pigeons to provide the means for return communications. This led to a distinct recognition of the value of ballooning for military purposes and hence the formation of a number of balloon detachments by the German army. So that in 1879, when Dr. Wilhelm Angerstein attempted to start an organization for the development of aeronautics, he was enabled to enlist the interest of a number of parties, particularly officers of the German army, and in 1881, there was formed the German Society for the Promotion of Aerial Navigation at Berlin. This attracted few meteorologists at first, but in 1887 there was a considerable influx of them into this organization. In June, 1888, the famous meteorologist Von Bezold proposed that the society make ascents of a scientific nature. This was acted on forthwith, the first flight being made on June 23, of that year, using a military balloon.

At this period the meteorologist Dr. Richard Assmann, who was greatly concerned with the problem of obtaining reliable temperature readings in the free air, developed his "aspiration psychrometer" which consisted of two thermometers, one wet and the other dry, enclosed in highly polished tubes side by side, with provision by means of a centrifugal suction fan at the top of the tubes for drawing a rapid stream of air past the thermometers. This was found to give accurate readings little influenced by exposure to the sun, thus permitting correction of the faulty results obtained by Glaisher.

Little by little the society was able to expand its work of scientific ballooning, first by assistance from military authorities and private individuals, then by the Royal Academy of Sciences at Berlin and finally by three separate grants of money by the German Emperor. Special balloons were built for this work, and by December, 1894, about 43 scientific manned-balloon ascents had been made.

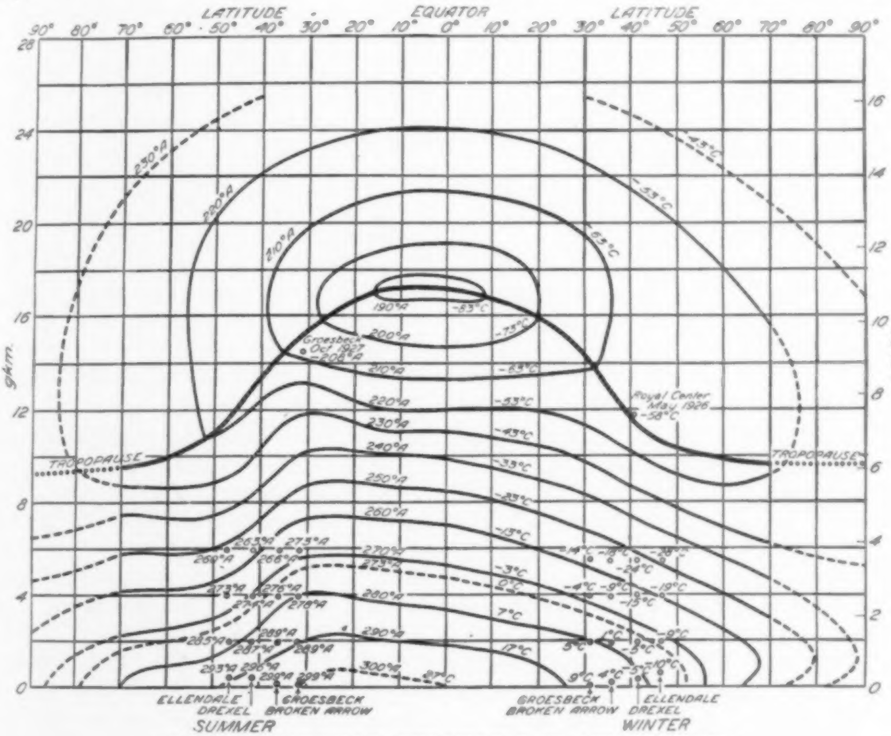
In the meanwhile, progress had been made along another line in France, for in 1879 Brissonet and in 1881 Jobert and Silbermann suggested that one might release small free balloons with tags attached, requesting the finder to communicate with the releaser and thus determine the direction of the upper winds. Consideration was also given to the possibility of attaching light self-recording instruments to the balloons to determine the temperature of the upper air.

Since such instruments were not available, the idea was not carried out, just as this limitation had blocked progress when the same idea had been presented in a prize problem given as long ago as 1809 by the Royal Society in Copenhagen. In 1891, Gustave Hermite and Georges Besançon began to work in this direction, and in March, 1892, they sent up small balloons, some of which carried a simple device for dropping cards periodically to permit the path of the balloon to be followed. Later that year they made small balloons of oiled paper or goldbeater's skin and constructed a primitive instrument consisting of an aneroid barometer to record the lowest pressure attained in the ascent and two thermometers, one to record the minimum and the other the maximum temperatures encountered. The first time this instrument was used the balloon was beaten down by rain;

however, between October 4, 1892, and December 10, 1892, they succeeded in launching 14 balloons with simple self-recording instruments, all but one of which were subsequently found. The maximum altitude attained in these experiments was about 9,000 m. (29,527 ft.).

balloon of 113 cubic meters (3,990 cu. ft.) capacity, containing illuminating gas, and released on March 21, 1893.

It attained the great height of about 15,000 meters (49,212 ft.) and recorded a minimum temperature of about –51° C. (–60° F.), thus establishing the first important record for meteorological



VERTICAL SECTION THROUGH THE ATMOSPHERE

SHOWING AVERAGE TEMPERATURE CONDITIONS AT VARIOUS LATITUDES IN SUMMER AND WINTER. THE THIN CURVED LINES, ISOTHERMS, PASS THROUGH POINTS OF EQUAL TEMPERATURE. THE HEAVY CURVED LINE, LABELED TROPOPAUSE, REPRESENTS THE BOUNDARY BETWEEN THE TROPOSPHERE AND STRATOSPHERE. THE FIGURES ASSOCIATED WITH THE SMALL CIRCLES REPRESENT AVERAGE TEMPERATURES AT FOUR STATIONS IN THE UNITED STATES: ELLENDALE, N. DAK., DREXEL, NEBR., BROKEN ARROW, OKLA., AND GROESBECK, TEX. (DIAGRAM ADAPTED FROM K. R. RAMANATHAN—SEE *Nature* (LONDON), JUNE 1, 1929.)

Proceeding further, Hermite and Besançon had constructed for them by the firm of Richard Frères in Paris an instrument weighing only 1.2 kg. (2.65 lbs.) for recording the barometric pressure and the temperature on a drum run by clockwork. This was attached to a sounding balloons (ballon-sondes), as these balloons were called.

Experiments with sounding balloons were quickly taken up in 1894 by workers in Germany, where the following year, on April 27, a balloon reached a maximum height of about 21,800 meters

(71,520 ft.). The instrument used in this country was that constructed by Dr. Assmann wherein the record was fixed on sensitized photographic paper and artificial ventilation was provided for the thermometers by means of a suction fan driven by a falling weight attached to a long wire.

The same idea was also carried out by Léon Teisserenc de Bort in France. However, the need for artificial ventilation was found to be unnecessary upon the development, separately by the last-named investigator and by the German meteorologist Dr. Hugo Hergesell, of a very light and sensitive bimetallic temperature element.

The use of sounding balloons spread rapidly to other countries after this, for at a meeting of directors of meteorological services held in Paris, September, 1895, there was organized the International Commission for the Exploration of the Upper Air, which took upon itself the task of securing international cooperation in this important field.

After consultations, November 14, 1896, was selected as the first day on which simultaneous ascents were to be made from a number of countries in Europe. On this day two balloons rose from Berlin and St. Petersburg, respectively, and one each from Munich, Strassburg, Paris and Warsaw, eight in all, four of which were sounding balloons and the remainder manned balloons.

Elaborately equipped observatories for upper-air investigations were established in the latter part of the period which we have been discussing, particularly the one at Lindenberg, Germany, and Trappes (1898) near Paris, France. At these places extensive programs of upper-air investigation were begun, and at Trappes, under the direction of Teisserenc de Bort, 258 sounding balloons were released between 1898 and 1902.

In the spring and summer of 1905, Dr. Hergesell made sounding-balloon ascents on the Mediterranean and Atlantic from the yacht *Princess Alice,* belonging to the Prince of Monaco. In 1906 and 1907 Teisserenc de Bort and A. Lawrence Rotch, of Blue Hill Observatory (Massachusetts), collaborated in making similar ascents, a maximum height of 17,800 meters (58,400 ft.) being reached.

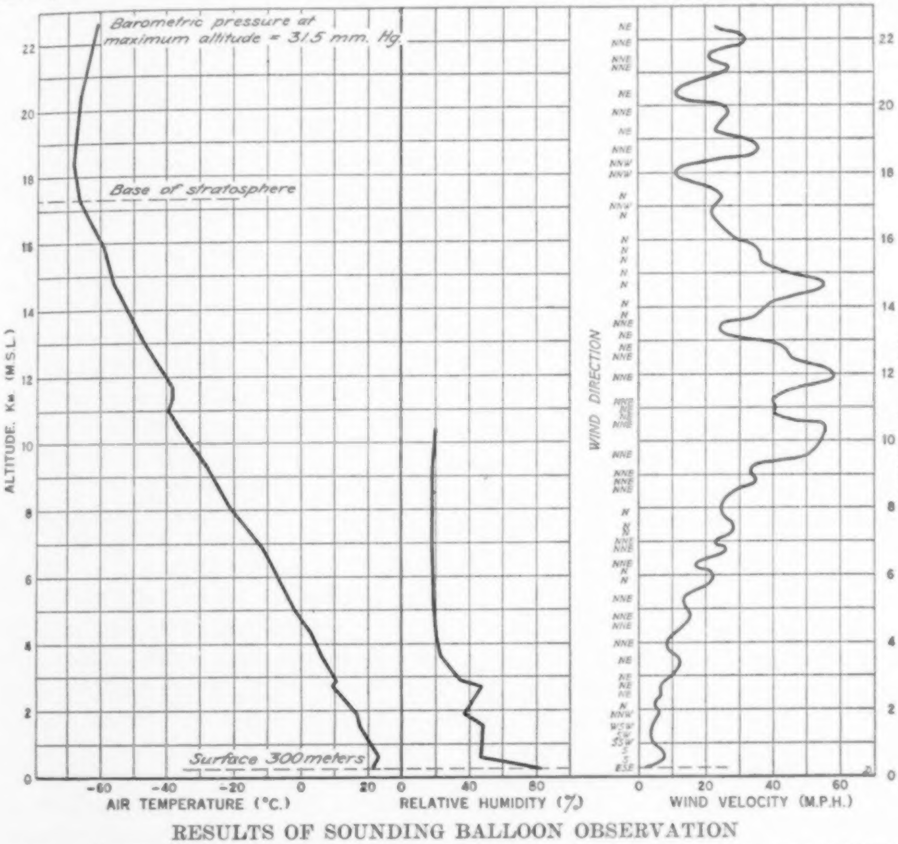
For this work the following scheme was evolved: the instrument is carried up by two balloons having dimensions such that one balloon is insufficient to give the necessary ascensional force. On the ascent one balloon bursts, allowing the other to descend slowly to the sea. The instrument is supported above the water and thus prevented from sinking by being attached between a float and the remaining balloon.

With the development which we have outlined, the inherent advantages of sounding balloons for purposes of exploring to great heights in the atmosphere became clearly evident; and open-basket manned-balloon flights for scientific purposes were gradually abandoned after having reached their culmination on July 31, 1901, in the ascent made by Drs. A. Berson and R. Süring of Germany to a height of about 10,800 meters (35,430 ft.), where they became unconscious despite the use of oxygen. It was thus with the aid of the sounding balloon that the stratosphere was discovered, first attention to it being called in 1899 by Teisserenc de Bort in a paper presented to the Physical Society of France, and again in a paper published by the same investigator in March, 1902, and independently in a paper by Dr. Assmann presented before the Prussian Academy of Sciences in Berlin on May 1, 1902.

Since 1899 much has been learned regarding the structure of the upper atmosphere, especially as a result of the free-air observations sponsored largely

by the International Commission for the Exploration of the Upper Atmosphere and by various meteorological services. Through the work of this commission international cooperation has so grown in scope that practically every civilized country on the globe now participates each year in an intensive program of upper-air soundings, covering some definite prescribed period such as a month. The comparative study of the data so obtained has led to a new branch of meteorology, *viz.*, the climatology of the upper atmosphere, some of the principal results of which we shall next outline.

The first illustration shows the launching of a sounding balloon at Omaha, Nebraska, Oct. 27, 1932. The balloon is made of thin rubber, with a total weight of 2 lbs.; its diameter is about 5 feet when released and its ascensional rate is 825 feet per minute. The parachute seen just beneath the balloon slowly carries the meteorograph down to earth after the balloon bursts. The maximum height ever reached by a sounding balloon is 35.9 km. (22.3 mi.).



RESULTS OF SOUNDING BALLOON OBSERVATION

MADE AT OMAHA, NEBR., 7:12–8:46 A. M., JULY 27, 1933. THE WIND VELOCITY AND DIRECTION WERE OBTAINED BY DETERMINING THE HORIZONTAL TRAJECTORY OF THE BALLOON AFTER OBSERVING IT THROUGH A THEODOLITE, AN INSTRUMENT LIKE A SURVEYOR'S TRANSIT, WHICH IS A TELESCOPE WITH HORIZONTAL AND VERTICAL CIRCLES FOR MEASURING ANGLES.

STRUCTURE OF THE ATMOSPHERE

If a celestial observer were to enter

the earth's atmosphere, he would find it subdivided into relatively thin shells. The lowest shell, which we call the troposphere, he would find to be rich in water vapor and characterized by the presence of numerous ascending and descending currents, which give rise to the formation and dissipation of clouds. Due to the heating of the earth by the sun, the remarkable power of water vapor to absorb radiant heat and the thermal effects of condensation, he would find the kilometer layer next to the ground the warmest, while above that he would note that the temperature fell with height at the average rate of about 0.6° C. per 100 meters (0.33° F. per 100 ft.) over a layer about 4 km. (13,120 ft.) thick, and still further above, that the temperature fell at the average rate of about 0.8–0.9° C. per 100 meters (0.44–0.49° F. per 100 ft.) up to a height in middle latitudes of about 11 km. (36,090 ft.), which is nearly the upper limit of the typical forms of clouds.

At this level he would discover a sharp change, for the temperature, instead of falling with increasing altitude, would be observed to remain essentially constant for a layer up to at least 35 km. (114,800 ft.). This upper layer or shell, which we call the stratosphere, he would find to be poor in water vapor and characterized by the relative absence of ascending and descending currents and of clouds. Since in general there can be no considerable amount of vertical convection in this region, motion must be largely horizontal or stratified, hence the name "stratosphere."

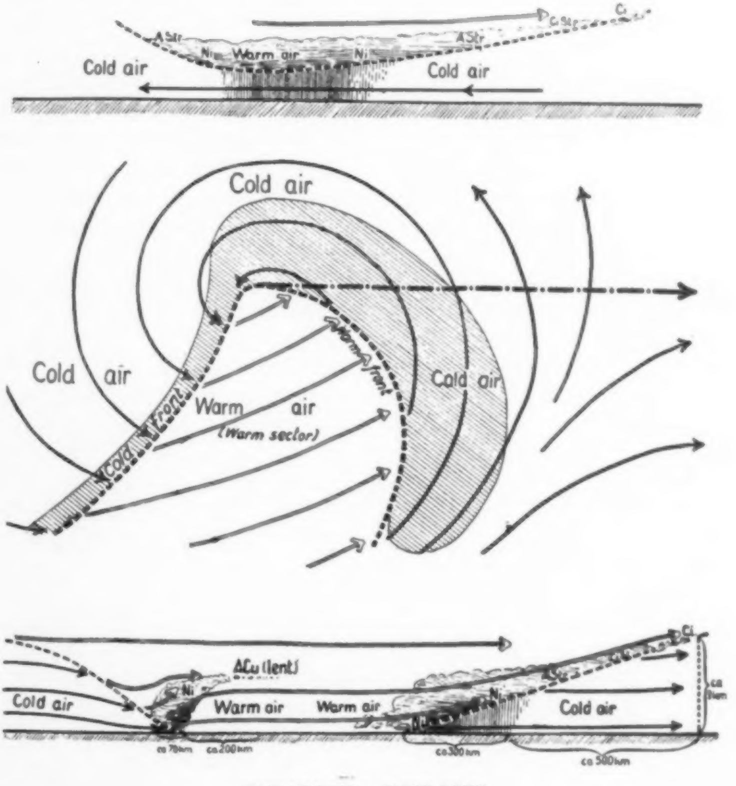
Our celestial observer would note that the lower shell or troposphere was not of uniform thickness over the earth, but that it had a hump over the equator to an extent of about 11 miles, while it tapered off toward the poles, where it reached only a height of about 5 miles. He would also make the perhaps astonishing discovery that the temperature at the top of the troposphere or base of the stratosphere was considerably colder over the equator than over the poles, namely, about −85° C. (−121° F.) in contrast to about −45° C. (−49° F.). In fact, he would find that the lowest temperature ever observed by man in the atmosphere was about −92° C. (−134° F.) in the stratosphere over Agra, India.

With regard to winds, our mythical visitor would find that they increase with height on the average until one reaches a level just below the base of the stratosphere, where the maximum occurs. Here, in temperate latitudes the winds will be found to prevail from a westerly direction with velocities of from 40 to 80 miles per hour. Over regions near the equator, on the contrary, the winds prevail from the east with velocities of about 25 miles per hour. Above the level in question the winds will have been observed to decrease in velocity within the stratosphere to values of about 15 to 25 miles per hour, while the directions will appear to have easterly components even over temperate regions.

If our guest from afar had appeared at the proper time some years ago, he would have seen carried aloft by sounding balloons ingenious devices for capturing samples of air at high altitudes and returning them to earth ready for analysis. The chemist assigned to this task would, in presenting his results to our visitant, explain that at altitudes of 14 km. (45,930 ft.) to which a particular device, for example, had ascended, the constituents of the air except for water vapor existed in essentially the same proportions as at sea level. If our visitant were to go to the laboratory of Teisserenc de Bort and ask him to explain how his device operated, the latter would demonstrate by placing the apparatus under a bell jar and evacuating

the space within. He would observe that when the pressure fell to a certain value, an aneroid barometer in the apparatus would cause an electrical contact, thus releasing a little weight which in falling would break the finely drawn-out point of an exhausted glass tube into which the maining portion of the drawn-out tube. The heat thus generated would melt the glass and seal the tube containing the sample of air.

If our visitant were to go further into the past and make an ascent to high elevations, in company with our balloonist



IDEALIZED CYCLONE

ACCORDING TO BJERKNES OF NORWAY. MIDDLE VIEW REPRESENTS HORIZONTAL SECTION THROUGH THE CYCLONE NEAR THE SURFACE OF THE EARTH. ARROWS INDICATE MOTION OF AIR PARTICLES WITH RESPECT TO THE CYCLONE. LOWER VIEW REPRESENTS VERTICAL SECTION THROUGH THE CYCLONE. CROSS HATCHING REPRESENTS CLOUDS; VERTICAL HATCHING, PRECIPITATION. UPPER VIEW REPRESENTS VERTICAL SECTION THROUGH THE CYCLONE AFTER THE "COLD FRONT" HAS CAUGHT UP WITH THE "WARM FRONT" AND LIFTED THE WARM AIR UP, THUS CAUSING PRECIPITATION.

air would rush. Upon further decreasing the pressure, the barometer would cause another electrical contact to be made and hence close a circuit containing an electrical battery and a wire of high resistance wound around the re- Glaisher, he would have observed that the sky became bluer as he rose and finally became a deep Prussian blue when an elevation of 6 miles was reached. At this elevation no ordinary sounds would reach his ear.

We shall now leave our visitor from afar and look briefly at some of the problems which still confront the meteorologist specializing in the study of the upper atmosphere.

Problems of the Upper Atmosphere

The first and foremost problem concerns the elucidation of the vertical and horizontal structure of the cyclones and anticyclones of the lower atmosphere which go to make up our daily weather. For this purpose in years gone by, meteorological services made use of box kites to elevate instruments, called meteorographs, which automatically recorded the barometric pressure, the temperature and the relative humidity of the air. While this method gave valuable results it had the limitations that kites could not be flown in light winds, elevations exceeding 3,500 meters (11,480 ft.) were not often secured, and much time was consumed in the actual flying of the kites. This method has therefore been superseded by that in which airplanes[1] carry the meteorograph rapidly to elevations of 5,000 meters (16,400 ft.) or over and return within $1\frac{1}{2}$ hours. The results thus obtained are telegraphed to the various meteorological centers for use in daily forecast work.

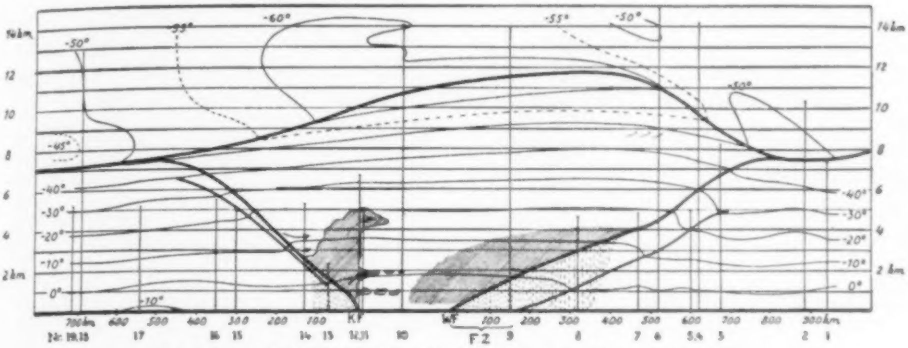
To obtain information for this purpose up to higher levels, other methods are necessary. With this problem before them, ingenious meteorologists and instrument makers of various countries, notably Moltchanoff of Russia, Duckert of Germany and others, have developed radio sounding-balloon meteorographs, weighing only about 3 pounds, which periodically send signals back to earth depicting the pressure and temperature conditions traversed during the ascent. These instruments were used during the International Polar Year from August, 1932, to August, 1933, at a number of stations in Polar regions.

The principle of radio direction finding has also been applied to balloons, using a base line of two receiving stations to determine the direction and velocity of the winds in the free air shown by the horizontal trajectory of the balloon as it is carried bodily along by the streams of air. If the two types of radio instruments mentioned can be combined into one instrument of compact and inexpensive design, a long step will have been made toward the desired goal.

Since finances play an important rôle in determining the extent of meteorological investigations, Jaumotte of Belgium has designed an inexpensive sounding balloon meteorograph weighing only 30 grams. No clock is used in this instrument, and the record is made on a piece of smoked mica the size of a postage stamp. This is projected optically on a screen to give high magnification and accuracy.

Of late years the plan has developed of releasing sounding balloons at intervals of 2 or 3 hours at a network of stations and thus reconstructing vertical cross-sections of the cyclones and anticyclones passing over the network. This has led to modification of many of the ideas held by meteorologists years ago. It has been of especial benefit in the study of weather from the view-point of the Norwegian or Polar Front Theory of the cyclone which holds that the cyclone develops as a result of the interaction of two streams of air, one cold and relatively dry of polar origin, and the other warm and relatively moist of tropical origin. Observations show that the cold air ordinarily moves as a mass with its boundary edges inclined to the ground at a small angle. These boundaries form discontinuities or sharp changes in temperature, and their intersections with

[1] Beginning on July 1, 1934, the United States will have a total of 24 airplane weather stations by cooperation between the Weather Bureau, Army and Navy.



VERTICAL SECTION THROUGH AN ACTUAL CYCLONE

ACCORDING TO BJERKNES AND PALMÉN (BEITRÄGE ZUR PHYSIK DER FREIEN ATMOSPHÄRE, BAND XXI, HEFT 1, LEIPZIG, 1933). THIN CURVED LINES REPRESENT ISOTHERMS. UPPER HEAVY LINE REPRESENTS THE TROPOPAUSE. HEAVY SLOPING LINE ON THE LEFT REPRESENTS THE UPPER BOUNDARY OF THE WEDGE OF COLD AIR FOLLOWING THE "COLD FRONT" (KF). HEAVY SLOPING LINE ON THE RIGHT REPRESENTS THE UPPER BOUNDARY OF THE WEDGE OF COLD AIR PRECEDING THE "WARM FRONT" (WF). VERTICAL LINES REPRESENT THE POSITIONS OF THE 19 SOUNDING BALLOON ASCENTS WITH RESPECT TO THE CYCLONE.

the ground are known either as "cold fronts" or "warm fronts." The raising (and hence cooling) of warm moist air up the slope of the cold air is believed to be a principal cause of precipitation.

A problem which has not yet been solved is the relation of the stratosphere to the cyclones and anticyclones of lower levels. The evidence now appears to point to horizontal mass movement, or advection north and south, of layers of air comprising not only the troposphere but also part of the stratosphere as primary factors in the development of the daily weather situations.

Further developments lie in the direction of exploring the higher reaches of the stratosphere, which to date has only been probed to a height of 35.9 km. (22.3 miles) in the sounding balloon ascent made at Hamburg, Germany, on September 8, 1930. Possibilities toward the attainment of this end may be found by applying heat artificially to the rubber envelopes of the balloons and to the hydrogen gas. However, it seems more probable that the solution may be found in the employment of rockets shot up to high altitudes. The projectiles fired by the Big Berthas which bombarded Paris from a distance of 75 miles reached altitudes of about 24 miles, so that these weapons of war may be turned to the purposes of peace and the advancement of science, if used to capture samples of air and perform other tasks of value.

The layer of ozone which spectroscopic observations indicate must exist in the layer between 35 and 60[2] km provides a field for further investigation. Its importance biologically can not be underestimated, since the solar rays which strike the atmosphere and are absorbed by the ozone would become lethal if the ozone were to disappear. This absorption of radiant energy by the ozone is believed to bring the temperature of this layer to values perhaps 50° C., or more, higher than those experienced on the earth during a summer day. The theoretical evidence for this is supported by the study of the velocity of sound in the

[2] These figures for the height of the ozone layer were believed to be true until quite recently. Authorities are now coming to the view that about half of all the ozone in the atmosphere exists below a height of 24 km., and that the maximum concentration occurs at a height of about 30 km. It is now also believed that nearly 10 per cent. of the ozone lies between sea level and a height of 8 km.

upper atmosphere following explosions at the surface. In this manner also is explained the zones of abnormal audibility noted so frequently during the world war.

From the drift of meteor trails in the upper atmosphere it has been possible to compute the direction and velocity of the winds at high levels. Many curious phenomena in this connection still require physical explanations. The heights at which meteors become visible are also employed as a means of estimating the density of the upper atmosphere and hence the pressure and temperature of the air at levels inaccessible to the sounding balloon. In this way temperatures of from 75° to 125° C. have been estimated at altitudes as high as 160 km.

Though the stratosphere is usually free from clouds, two kinds are occasionally observed there, and then only at night near the horizon toward the sun just before sunrise or just after sunset. Both of these types exist far above the height of the highest clouds found in the troposphere. The first type, the nacreous or mother-of-pearl cloud, is found at an altitude of about 25 km., and the second type, the noctilucent cloud, is found at an altitude of about 82 km. Both are generally visible only when the sun is below the horizon and illuminates their lower surface. The lower of these clouds are iridescent, as their name implies, and are believed to be formed of supercooled water droplets. The upper of these clouds are silvery or bluish-white in color, and may be formed of matter ejected from volcanoes or even possibly supercooled water droplets. The nature and origin of these clouds therefore require elucidation.

For a number of years meteorologists believed that in the upper atmosphere the heavier gases, such as nitrogen and oxygen, tended to sink by diffusion, leaving the lighter gases, such as helium, to exist in higher degree at great elevations. Evidence obtained from spectrophotographs of auroral displays and from other considerations now, however, points to the conclusion that nitrogen and oxygen, the latter possibly atomic in large measure, exist to great heights and that hydrogen and helium may be present only in minute quantities near the upper portion of the atmosphere. Here then lies a fertile field for further investigation: To determine the distribution of temperature, pressure and composition of the gases present, including water vapor and the elusive ozone whose variations with place and time are so mystifying.

At heights yet greater than those we have referred to, there still exist phenomena of interest to the meteorologist, *viz.,* the aurora at elevations from 100 to about 1,000 km., and the Kennelly-Heaviside ionized layer at elevations from about 80 to about 260 km. Both of these are known to have some relation to electrical and magnetic storms on earth, while the latter is known to cause the reflection of radio waves back to earth. Recently Martyn of Australia reported that when the average night-time ionization density in the E layer of the Heaviside layer showed an increase or decrease, the barometric pressure at the ground from 12 to 36 hours later showed a corresponding increase or decrease. If this is borne out, we have evidence that the changes of weather we observe at the surface of the earth are in some manner brought about by the same agencies as produce the changes in ionization at high elevations earlier, and/or possibly that conditions at 80 or more km. have a causal relation with the following weather at the surface. This opens vistas unseen years ago and indicates to the meteorologist that he may have to turn to the laboratory and avail himself of the new tools that science has developed in order to fully understand the sequences of the weather.

THE COSTS OF MEDICAL CARE

By RAY LYMAN WILBUR, M.D.
PRESIDENT OF STANFORD UNIVERSITY

SCIENCE has acted like a ferment throughout our whole civilization. The changes brought about by it have been so rapid that they are beyond the conception of most of us. We have completely rearranged our environment without any material change in ourselves. The social responses to the effects of science have been slow and the political ones even more so. Modern medicine built on science has been in the forefront in bringing about these changes.

We now find ourselves with a great mass of usable facts and with a splendid body of trained men and women ready to apply them for the benefit of humanity, but without an administrative or economic system which will give all members of our society an even or an adequate opportunity to profit by them. In every advance there are always those who struggle against it and those who must fight old enemies in order to be happy. The mould of the human thought machine changes very slowly. The pattern of emotions, prejudices and habits that make up a large part of human behavior is strangely resistant to the control of what we are pleased to call the intellectual processes.

There is no emotion in science. Its control depends upon the keenest and cleanest use of the mental faculties. It is natural that a considerable portion of those dealing with the sick should have their faces turned toward the past and that they should endeavor to use old formulae for new conditions. The automobile and the associated highways have changed all the time factors in medical practise. The automobile, the operating table, the microscope, the telephone, the test-tube, the Roentgen ray, the trained nurse, the interne, the mechano-therapist, are indispensable to the modern doctor. Each has its place and each costs money. We can not care for the intricate set-up of modern medicine by a bookkeeping system such as that of the past, which was built around the notes carried in the silk hat of the bewhiskered, lovable and friendly general practitioner.

Medicine has been built up step by step through persistent experimentation. The social applications of medicine require the same repeated and carefully controlled experiments. We should recognize that the scientific side of medicine is up-to-date and in full synchronization with the peaks of human achievement, while for the most part the social side and the economic side as developed now are often archaic and ineffective in operation.

The medical profession has been undergoing a dramatic transformation in the last twenty-five years. Just as civilization has been remoulding its environment, so medicine has been remoulded by those instrumentalities that are supplementary and accessory to the use of the trained mind and the trained hands of the physician.

In this country we have had the construction of great medical schools and laboratories. We have put hundreds of millions of dollars into hospitals. We have trained tens of thousands of nurses and technicians. The mere operation of the machinery of modern medical practise requires great administrative skill and enormous expenditures. The physician can no longer be independent of these great agencies. He can, though, command them and see that they are used for their highest purposes. But in order to do so he must take part in the business, social and economic reorganization that is required, so that these instrumentalities may function and so that he may do his share in seeing that all elements of the population receive a just

and fair proportion of medical attention. To bring this about, community coordination and some orderly plan that will provide the facilities and that will remunerate the physician and his associates must be worked out.

Out of the population in a given year only so many are sick. Of the people who are sick a considerable number are indigent and automatically fall into the taxpayer's pocket. The others belong to different economic groups. In America we have been on the way up all the time. We have not thought of a stratified society. We think of a constant rise of young men and young women from the bottom to the top. These young people want the very best medical care in the very beginning of their economic period of earning a living. We can picture readily the burden of sickness that strikes our nation in the course of any given year. We can prophesy just about what it will be in character as well as in extent; but no one can prophesy what the burden of sickness will be in so far as the individual is concerned. Only a comparatively few are sick, and yet those few must bear the heavy medical costs. The hospitals, the various laboratories, the dentists, the nurses, all come in for their share. The great mass of men and women want to pay their own way. They want to meet the costs of medical care. This is impossible at the present time unless we devise a method that will spread the payments over a much longer period of time than just the period of an illness. We must spread it, too, over large numbers of individuals rather than over a few. In other words, there must be periodic payments over a long period of time to provide for the concentrated costs of illness. Otherwise they can not be paid. This means that an insurance basis must be devised to give security to the physician and care to the sick.

The Committee on the Costs of Medical Care during its five-year study brought out many pertinent facts which can not be blinked. Most significant perhaps is the uneven blow which sickness strikes in the community. Among 4,560 families who kept records of their total medical charges during a year, we found a wide range of charges per family. There were 1,788 of these families whose total annual incomes for the year were under $2,000 per family. Forty per cent. of these low-income families incurred medical costs for the entire family of less than $25 for the year, 20 per cent. had charges from $25 to $50, 21 per cent. from $50 to $100, 14 per cent. $100 to $250, 4 per cent. $250 to $500, 1 per cent. $500 to $1,000 and 0.2 of 1 per cent. $1,000 to $2,500. Eighty-one per cent. of this group had bills of less than $100 for the year and, we may assume, could pay their medical charges without serious hardship, but the remaining 19 per cent. must impair their living standards, draw on savings or borrow money if they are to meet their expenses. The 81 per cent. paid only 36 per cent. of the total bill of the entire group, while the 19 per cent. were faced with 64 per cent. of the amount, making the average per family eight times as high in the latter group. Among the higher income groups, the situation is roughly similar. In any particular year most families have moderate medical expenses in view of their total incomes, while a few families, perhaps 20 per cent. of the total, are taxed beyond their means. Next year, fortunately, a somewhat different group of families will constitute the 20 per cent.

The essential fact is that medical charges fall with great unevenness on different families during any given year and on the same family during the course of several years.

No well-informed student of medical economics believes for a moment that the patient's difficulty in paying medical costs is primarily or basically due to excessive fees on the part of physicians and other practitioners. There are a few "gougers" in medicine, of course, just as there are in all walks of life; but any

impartial analysis of the incomes of physicians leads to the conclusion that in view of the time devoted to training and education and the responsibilities assumed, there is no general overpayment of practitioners. For instance, the 79 practising physicians in San Joaquin County, California, had a median net income in 1929 of $5,500; in Philadelphia 245 representative physicians reported net incomes for 1928 for which the median was $4,200; 137 Vermont practitioners reported net incomes for 1929 with a median of $3,400; and 30 physicians in Shelby County, Indiana, had a median income in 1928 of $3,100. Some unpublished data regarding physicians south of the Mason-Dixon line indicate that conditions in certain large areas of the South are such that large numbers of physicians in 1930 received net incomes of less than $1,000. On the average the general practitioners reporting have net incomes about half as large as the specialists. Dentists in twenty states reported median net incomes for 1929 of $4,000.

Most of these figures are for 1928 or 1929. In 1930 physicians' incomes fell off appreciably, and at present the situation is doubtless even worse. In fact, one of the most significant aspects of the practise of medicine in the United States is the financial precariousness and insecurity of the major practitioners concerned.

It is obvious that we can not assume that the payment problem arises primarily because physicians receive incomes that are too large. Its roots go deeper than that. It rests on two principal bases: First, the physiological nature of the human structure, and the resulting uncertainty, so far as the individual is concerned, of the time and the place and the nature of the illness or illnesses which will affect him; and second, the uneven distribution of wealth in the United States and the apparent inability of a considerable number of people to do more than meet their current expenses. We feel reasonably confident when we say with Hermann Biggs, "*Public* health is purchasable." Our experience has been that if we perform certain tasks faithfully and conscientiously our mortality and morbidity rates will fall. But to the *individual*, we must be much more guarded in our promises. We may assure him that he can avoid diphtheria and smallpox and probably typhoid fever and certain other diseases. We can point out the benefits of sane, wise living, of reasonable exercise, of adequate rest and of proper diet. We can suggest an annual physical examination. Yet, although the individual may faithfully follow our advice, we can not assure him that he will escape all expensive illness. For the *group* we can now predict with a fair degree of certainty the incidence, duration and severity of the illnesses which they will have; for the *individual* definite prophecy is impossible.

In the light of this uncertainty it is easy to discern the psychological barrier to saving money in anticipation of an uncertain attack of illness which, if it comes, will cost an unpredictable amount. Even if a family does save, it has no way of assuring itself that the saving will be adequate.

But the uncertainty and the resulting adverse psychology are not the only obstacles. We must also face the fact that we distribute the fruits of our economic harvest in such a way that numerically important sections of our people have little surplus after paying even minimal amounts for food, clothing and shelter. In 1926, according to a careful estimate, 32 per cent. of the families in New York received annual incomes of less than $2,000 per family and 48 per cent. received less than $2,500 per family. In a large majority of cases this income represents the earnings of more than one member of the family. Most of these people can pay something for medical service and, if fully employed, they are able to pay their medical expenses during times of normally good health. But

a serious illness involving hospitalization and special nursing as well as the services of one or more physicians quickly bankrupts them.

Paradoxically enough, the problem has been sharpened by the very advances in medicine on which we pride ourselves. As automobiles have improved in quality, they have been more widely sold, and as a result have decreased in cost. But the greatest danger an economist runs in probing the economics of medicine is that he will expect to apply the automobile techniques and criteria and will not realize the deep significance of the difference between a personal, professional service and an impersonal, manufacturing or commercial process. In medicine, as our methods of measurement, of observations and of treatment have grown in objectivity and precision, they have of necessity in many cases become more, rather than less, costly. The saddle-bag day of medicine has passed and the new era has brought us new problems. We can not disregard modern methods. Although we all realize that complicated laboratory equipment is no substitute for the careful, thorough attention of a skilled mind, we also realize that if we are to practise medicine scientifically, if we are to do our best for each patient, we must have available many expensive tools and must utilize many procedures that were unknown to our grandfathers. Good medicine to-day has to be more costly than the good medicine of even twenty-five years ago.

The provision of adequate scientific medical service to all the people, rich and poor, at costs which can be reasonably met by them in their respective stations in life, is of vital concern to every one here in this country, for in every city, town and village are people suffering from rheumatism, cancer, venereal disease, diabetes, tuberculosis and other ailments. Thousands of persons, even in "good times," try to get along without the medical service they need. Hundreds of thousands postpone seeing the physician or dentist or going to the hospital because they are afraid the charges will be too high. Even among the wealthy it is only a small percentage who obtain all the preventive care that they really need.

This lack of adequate medical service lays a burden of pain, suffering and inefficiency on this nation which, rich as it is, exceeds what we can afford. The question which faces the American people in the next ten years is not whether we can afford to provide ourselves with satisfactory medical service, but rather whether we can afford to provide less than adequate health care.

The Committee on the Costs of Medical Care agreed that a satisfactory medical service was one which would fully meet the following essentials: (1) Safeguards the quality of medical care and preserves the essential personal relation between patient and physician; (2) meets the true needs of substantially all the people.

It should provide service on financial terms which the people can and will meet without undue hardship either through individual or collective resources. No one who has examined the data which have been gathered by the committee can doubt that the cost of medical care often constitutes a serious obstacle to a proper distribution of medical service.

A satisfactory medical program also must utilize known preventive measures. The old saw about "an ounce of prevention" is vitally true in the medical field. If we are to keep the costs of medical care within reason, we must make our major economy through the prevention of disease.

Our problem requires that we make full use of existing medical facilities, which can best be done by organizing many of them into medical centers; that we retain in any program the confidence and support and leadership of the trained medical profession, without whom no satisfactory plan can be

brought into being; and that we provide some form of payment for medical services which will spread the load over both sick and well and over all elements in the population. I see no escape from the insurance principle if medical care is to be given to those who need it and the physician and hospital are to be paid.

What difference does it make to a physician whether he is paid directly from the checking account of the patient or from a collective fund to which the patient has contributed? The essential thing is that the physician and not a bureaucrat determines all medical phases of the care of any patient, and that the patient has a voice in the selection of his medical attendant.

When we come to the question that was faced by the committee as to whether these group payments are to take the form of voluntary or compulsory contributions, naturally we meet differences in view-point that can only be worked out in time. We felt in the committee that it was safer to start off with the voluntary method, for we feared that the compulsory method carried out too soon with vigor and enthusiasm of legislative bodies (which might have members who want to be reelected on a popular cause) might project us into a field from which we might later wish to retreat. But if, after a few years, we have been able to demonstrate that there is a willingness to meet this charge, and that only those who fail to meet it are reluctant or negligent or indigent, then we can see our way toward some plan that may have the compulsory feature in it. In other words, we can develop a plan of compulsory health insurance gradually, if that should prove to be the answer.

The costs, as brought out by the committee, are not staggering—$20 to $40 per person per year. Using our present facilities, it is not a great cost when we think of how much many pay now who have more than the ordinary amount of illness to face. If we organize our talent for producing medical services economically and efficiently, a task well within the scope of America's peculiar genius, if we give thought to our navigating problems and plan our course to take fullest advantage of the wind, the waves and the strength and speed of our ship, we shall undoubtedly find that the cost is not too great for our present society. For inadequate medical services, produced with all the wastes inherent in individualized practise, we now pay about $30 per capita annually. With organized, coordinated effort we should be able to provide ample medical services of good quality to *all* the people and with proper remuneration to the professional personnel for a cost of somewhere between $20 and $50 per capita per year.

Throughout the nation we have had many different schemes given a trial. There is a tremendous ferment working in our medical system. Both doctors and laymen are reaching out in various directions to find methods of leveling the cost of medical service and of providing a better quality of care than has previously been available. Where this evolution will take us, we know not. That it contains dangerous as well as hopeful possibilities is apparent. If the costs of medical care can be approached without prejudice and preconception, if we can get the doctor to go at this problem of the social reconstruction of medicine in the same way he would take up the treatment of an old disease by a new method we can offer to the American people the greatest opportunity for happiness that can come to them from any present source.

It seems that American ways of providing medical care for all on a basis that retains dignity and self-respect are available. By cooperation and weighed experimentation the best plans can be rapidly evolved on the basis of the facts presented by the Committee on the Costs of Medical Care.

ETHICS AND RELATIVITY

By Dr. E. A. KIRKPATRICK
LEOMINSTER, MASS.

WRITING on "The New Burden of Behavior" in the October SCIENTIFIC MONTHLY, Dr. Patrick suggests that the time is ripe for the application of scientific methods to problems of behavior. The present writer has been studying the possibilities of so doing for the past ten years and believes that changes produced by science are decisively influencing ethical practises and beliefs and that scientific research will ultimately solve many ethical problems. Perhaps, as Dr. Patrick says, we need a genius like Einstein to tell us "not about space and gravity but how to behave in this new and perplexing world—and why." We have had many able philosophers who professed to do this, yet they have had little effect upon the behavior of the great mass of human beings. Rarely have the theorists themselves lived in accordance with the ideals set forth. Even those who realized the impossibility of living ideally surrounded by a naughty world, and who therefore constructed imaginary social utopias, have had little influence on sociological organizations and codes of conduct. Human beings go on their way almost as independent of moral theories as the stars are of physical theories of gravity.

I

Most of the real progress in astronomy has been made by careful students of facts rather than by physical theorists. It is the student of the relative movements of the planets who has made it possible to predict the exact location of any planet at any given date in the future. In ethics we need, not so much theories of how man ought to behave as studies of how he does behave, which will enable us to predict how he will act under given conditions.

Man's characteristic behavior can not be determined by studying the nature of individuals only, but by studying the behavior of man in relation to his environment, physical and social. Only a little observation is necessary to show that everywhere men living in groups engage in common practises approved by all, and that they frown upon and usually punish acts contrary to these accepted ways of behaving. In other words, they develop ethical or moral standards by which they determine what is right or good. These standards are never quite the same for any two groups of people, and they are all subject to change. This means that the standards are relative instead of absolute, as supposed by theoretical moralists. The science of astronomy is not vitiated by the acceptance of the theory of relativity in physics but is made to seem more reasonable thereby; and a similar result may follow the acceptance of the doctrine of relativity in morals. We must study the underlying forces manifested in human behavior and find out what general truths account for the gravitation of human behavior to definite forms approved, at least for the time, by nearly all, and practised by the majority.

II

Without attempting at present to describe the essential elements of human nature, we will give attention to man's responses to his environment. He is continually reacting: (1) to material things; (2) to the customary reactions of those around him to things; (3) to the customary reactions of the people

around him to each other; (4) to the special reactions of other people to him as an individual. We may study human beings in all parts of the globe and in all stages of history and discover general truths of how the behavior of each group is influenced by these four phases of the environment.

(1) There is sufficient similarity and permanency in the characteristics of objects and in the nature of all human beings to insure that the reactions of all persons to objects, when uninfluenced by customs or people, will be very similar. They will all react negatively to painful and dangerous things, and positively to those giving safety and comfort. However, their knowledge of how to avoid what may be dangerous and to secure what is satisfying differs greatly. Since knowledge gained by individual experience only is very limited, many reactions to things fail to give the safety and satisfactions desired.

(2) The second phase of the environment, the customs of the group in the use and avoidance of things, is based on the much wider experience and knowledge of the older members of the group and also of their ancestors. In reacting to these customs in a conforming way, one's reactions to things are relatively better in the sense of improving his chances of survival and comfort. These customs, however, are subject to change, especially after things have been studied by the more exact methods of experimental science. In our present civilization men are more and more directing their reactions to things in accordance with the results of scientific research, rather than according to their own observation or the customs of their elders. They are inclined positively toward what science shows to be healthful and satisfying, and negatively toward what science indicates is dangerous and unpleasant, and hence old standards of conduct are breaking down. In its very nature science is universal, and as its sway spreads it brings into use the same objects of nature and the same inventions and thus tends to make the reactions of all peoples to things more nearly alike in fundamentals, although special objects and situations induce people to live somewhat differently in one locality than they do in other places. Economic, medical and social reactions, so far as they are directed by scientific knowledge, tend to become nearly the same the world over. Injurious economic practises, the use of inefficient medical methods and ignoring social welfare become matters of right and wrong in the light of science. To fail to provide economic security by insurance or otherwise, to fail to disinfect surgical instruments, to keep large numbers of insane persons in strait-jackets or to fail to educate children—all these things are now universally regarded as wrong. Thousands of ethical codes are developing as the result of scientific findings and are securing world-wide adoption.

(3) The third type of reaction, which is to the customs governing the relationship of individuals and social classes to each other, is less quickly, directly and evidently modified by mechanical inventions and the growth of scientific knowledge, and yet it is just as surely being changed.

Among nearly all peoples in past history, customs have decreed that members of families behave toward each other in certain ways, that behavior towards members of one's own community, tribe or nation be different from that toward members of other groups and that certain individuals—kings, priests or persons of different social status—shall practise and require special types of behavior regardless of the individual characteristics of the king, priest, aristocrat, or what not. These customs were associated with beliefs that such persons really differed from ordi-

nary persons. The effects of increased knowledge of physiology and psychology is to reveal all persons as fundamentally the same, and this leads to customs of behaving to a greater and greater extent in essentially the same way toward persons of all classes, and to expect the same behavior on their part. These ideals are gradually becoming established customs to which the new generation is conforming; hence the decay of reverence.

In most civilized countries it is now agreed that all persons are equal in the eyes of the law, and public opinion approves of the same general type of behavior toward people of all classes. International law also recognizes no social difference when one nation demands of another protection for its subjects. With further development of scientific knowledge and of facilities for travel and communication, there will be world-wide approval of the same types of behavior in most details towards all men. When these tendencies have developed further, conflicts between classes and nations, arising from the belief of each that they should have special favors in the way of behavior toward others and of others toward them, will cease. The same regulations will then apply to all classes and nations, and the majority of nations and the mass of people in each nation will unite in supporting such regulations. There will then be resistance only by a minority who are striving for special treatment favorable to themselves.

(4) The fourth form of reaction to phases of the environment, that of reacting to individuals, is still less directly and evidently modified and controlled by increased scientific knowledge, and yet it is subject to the same influence. Human beings are not all alike: there are fundamental differences between (a) the sexes, (b) children and adults, and (c) individual adults who vary in physical strength, intellectual ability and in emotional and volitional characteristics. This makes it inevitable that the interactions of individuals as individuals to each other shall be influenced by these differences. Repeated reactions of the same individuals to each other render the behavior of each toward the other as of a still more special character.

(a) The universalizing of knowledge, however, may have very marked effects upon the behavior of these naturally different types of persons to other types. This is most evident in the case of the behavior of the members of the two sexes toward each other. Old ideas as to the differences between men and women and of the correct behavior toward each sex have been greatly changed in the direction of recognizing their fundamental physical and mental similarity and to corresponding changes in customs of behavior more nearly the same toward all. When the sciences of physiology, psychology and sociology have been further perfected and customs correspondingly modified, the approved hetero-sex behavior will still differ in certain details from the approved intersex behavior, while most other behavior reactions of the two sexes will be on nearly an equal plane, as they now are economically and politically in the United States. The recent changes in women's behavior and in men's reactions to these changes in all civilized countries and especially in Russia, while not due wholly to increased knowledge of the near equality of men and women, will inevitably be perpetuated in a scientific world. In other words, science will determine the types of behavior which will be generally approved and practised in dealing with the same and with the opposite sex, although individual men and women will behave in special ways toward each other.

(b) The differences between infants and adults and, if family life continues, the necessarily intimate interaction between parents and children will make

inevitable certain differences between behavior of adults and parents toward children and of children toward parents and other adults. These differences are especially marked during the period of helpless infancy, but as fast as the child gains power of self-direction, the reactions of adults to children and of children to adults need to be varied only on account of differences in strength and knowledge. The right of the parent to demand obedience and the duty of the child to render it is now questioned in the light of scientific truths of mental hygiene for both adult and child.

(c) The relationship between strong and weak individuals of whatever age, and of intelligent and ignorant, will always be of a somewhat special character. They can not compete on an equal basis, and the tendency is for the stronger and more intelligent person to dominate the weaker and more ignorant, either to the advantage of the strong, or because of love, to act in the interest of the helpless and innocent. Scientific studies of personality and of mental hygiene, however, show that conflicts are decreased when persons of differing ability cooperate in gaining common ends instead of one dictating the ends and directing the activities of the other. Such cooperation is greatly increased in an age of specialization and of scientific domination. In polite society, in schools, in industrial establishments and in institutions of nearly all sorts (armies partly excepted), authority is giving place to cooperative and reciprocal behavior in reaching common and special ends.

In the early days of the factory systems authority grew, but is now declining, and employers and laborers, when they can not completely cooperate, are more frequently agreeing upon behavior involving reciprocal advantages. Scientific management is now concerned not only with elimination of waste of materials and movements, but with methods of dealing with employees and with the formulation of codes for the conduct of industrial and business activities. Fact-finding commissions are numerous, and legislators, courts and leaders of public opinion are more and more rendering judgments of ethical behavior in the light of scientific findings rather than on the basis of old customs.

III

In order to see more clearly the part that science may play in determining behavior we must take note not merely of the effects of environment upon the reactions of men, but must study human nature and note some of the laws governing the adjustive reactions of men to other men. It is natural for all men to adjust their reactions not only to their physical environment but also to their companions in such ways as to secure their own continued existence and satisfaction. This means that they inevitably modify their own behavior by what they know is likely to be the response to their acts from their fellows. This tendency is especially evident when one is surrounded by equals who can make their approval or irritation effective. In general, an aggressive act excites aggression in others, while a kindly act induces helpful ones. The aggressive acts of two persons or groups often increase in intensity with each response of the other, but after repeated conflicts each fighter learns to avoid going too far because of what the other is likely to do. As a consequence, when the same parties are in frequent conflict some sort of rules of fighting usually develop which prevent either party from trying to exterminate the other without regard for age or sex or the means used. Fighting with fists, with weapons in duels and with germs or gas in war have generally developed rules of civilized and uncivilized fighting, violations of which have been severely condemned. In competitive busi-

ness and in games, rules of behavior are always adopted and ultimately approved as right if they bring greater satisfaction to all concerned.

Putting the matter in brief form, whenever men react to each other frequently in similar situations, they sooner or later make adjustments, each in the light of how the other responds, until ways of reacting are found which in view of the action of the other party will be least unsatisfactory. Each is willing to do or to refrain from doing certain things if the other acts in a similar way and both gain thereby, *e.g.*, turn to the right. Customs of this kind cause each to expect the usual or right act from the other, and each assumes responsibility for obeying the same rule. Among all groups such codes of right develop. How quickly they develop and how effective and satisfactory they prove depends in part upon the frequency with which the same situations are met, and in part upon the disposition, intelligence and enlightenment of the reacting parties. Knowledge gained in part by experience and in part revealed by the science of social psychology will induce intelligent individuals to act on the general truth that all behavior must be adjusted, not merely to the objective situation, but in relation to the known or probable behavior of others. Codes of behavior that will more quickly bring about satisfactory conduct on the part of persons associating with each other may be formulated in the light of such knowledge and modified in the light of experience so as to secure general endorsement and conformity, *e.g.*, obey signal lights.

We see, then, that man's nature as a creature seeking to preserve his own life and health develops modes of action when he is associated with others which inevitably lead to behavior generally recognized as right. Such rules are more favorable to the survival and satisfaction of all members of the group than acting without regard to what others wish and are likely to do. In other words, acts approved by all are more satisfactory than acts for self-advantage which are not adjusted to the desires of others.

There is another side to human nature which must not be ignored in studying problems of behavior. Men's actions are not unfrequently determined more by their emotional attitude toward another person involved in the situation than by the possibilities of the situation itself. The value of a disputed piece of property or the success of cooperative efforts are often almost ignored in the effort to injure an enemy or help a friend. This purely personal factor influencing behavior to a greater or less extent involves actions which may be called "good" or "bad," without in all cases being judged by the group as right or wrong. The individual behavior of persons intimately associated renders the development of codes of conduct, based on scientific findings as to what is of general advantage to the group, very difficult. The politician still believes in being "good" to his friends, the civil service reformer in giving the most efficient man the job.

In general, the development and the observance of codes of right are hastened and perfected by all means that add to the general good will and are slowed or prevented by those producing ill will toward individuals and sometimes by developing excessive good will toward other individuals, regardless of how others of the group are affected thereby. Additional development of scientific knowledge of personality will doubtless result in more persons having the attitude of good will or loyalty to the group, and of more good will and less ill will toward individuals.

There is one way in which the effects of good will or ill will on the development and practise of moral codes are

now being continually minimized. Ill will and good will have the greatest influence on conduct when people are in face-to-face contacts with each other, and when each is acting according to his own nature rather than following a prescribed course of action. In all large organizations officers and employees when on duty are acting toward each other and toward clients in accordance with policies and regulations prescribed and practised by the leaders and managers and by the traditions of the institution. The customs of polite society also prevent many manifestations of personal attitudes which would otherwise call forth good will or resentment on the part of associates.

The results of inventions and discoveries of science have tremendously increased the number of non-face-to-face associations of people with each other. Buyers and sellers often never meet personally, while producers, transporters and consumers of goods and users of works of art and literature are rarely in personal contact with each other, and the codes of right behavior in their relations to each other are more influential than personal ill will or good will. Smiles and pleasant words contribute somewhat to the good will felt toward an organization; hence these are encouraged by business firms, railways, telephone companies and by educational and social institutions in dealing with individuals. Yet the security dealer or the head of any institution who seems over-solicitous regarding the personal welfare of a client is regarded with suspicion.

The importance of personal ill will and good will in the ethics of modern life has diminished to such an extent that we may raise the question whether in the social field a science of ethics of an almost completely objective character may not be developed, leaving only the field of reactions of individuals to individuals still not completely dominated by scientific findings. This problem of objectivity of ethical science may be discussed at another time.

IV

This article may be closed with a further brief reference to relativity. Many who have discussed ethical problems have seemed to assume that at least a *concept* of absolute right and of goodness is attainable. Scientific concepts, however, are all relative, and the author believes that no progress in the solution of ethical problems is possible until the idea of an absolute right is abandoned and the facts of man's reactions to things, to customs of his group and to individuals are investigated. The nature of an act varies with its setting and in relation to near and remote objective and subjective consequences. It would be useless to attempt to develop an absolute science of bridge building or of agriculture, and it is just as useless to strive for an absolute ethics. Notwithstanding the influence of custom on constructive practises, agricultural operations and ethical judgments, scientific knowledge will ultimately determine what practises will generally be approved.

Progress in developing efficiently right conduct in accordance with scientific knowledge is slower in ethical than in material sciences, but no less inevitable. Scientific knowledge is in its nature universal, and when it has spread to all nations it will make the essentials of ethical behavior the same the world over.

In studying ethical practises it is not necessary to decide what one thing is of the highest ethical value. All values are reflected in individual conduct, and since there must be adjustments of each individual's conduct to that of all other people affected by it, the codes of conduct finally developed and approved represent the resultant of the attempts

of all to gain what they regard as of most value. The values obtained by right conduct are the sum total of all known human values that are at the time practically obtainable by all. Other values dependent upon individual tastes, esthetic appreciations and personal effort may be attainable, but such values are not, properly speaking, ethical values because no uniform modes of acting are involved. In other words, there are many individual satisfactions not subject to general ethical valuation. Ethical conduct of individuals and the highest happiness of individuals are not identical.

Right is always relative to the approved practises of the persons most concerned and has varied extremely in different groups at different stages of human history. When all the world has come under the dominating influence of science the group differences will decrease, and the personalities of reacting individuals will be regarded as of less ethical significance. There is no reason to expect that right will ever reach a condition of unchangeability. Some peoples and some individuals will be relatively nearer to scientific right practises than others, and each will be influencing the codes and practises of the others. Science will also be advancing and new inventions and social organizations will always demand readjustment of ethical codes so as to make them relatively better. It is vain to hope that they will ever become such as can be called absolutely and eternally right and good, although some codes have worked well with minor variations in all groups of men in all ages, and hence may be regarded as more nearly approximating the ideal of the absolute, universal and eternal right which has inspired the thinking of moralists in all stages of the world's history.

The mills of human interaction grind slowly, but science is accelerating the adjustment of social organization and the emergence of finer working codes of behavior.

TO THE FUTURE BIOGRAPHERS OF JOHN QUINCY ADAMS

By Dr. H. G. GOOD

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THE recent biography of John Quincy Adams by Champ Clark[1] once again raises the question whether a biographer is at liberty to suppress or gloss over at will any of the leading activities or interests of his subject. Except for a brief chapter on the Smithsonian Institution, this biography has no word, good or bad, for the work of Adams in the promotion of science; and that chapter, indeed, does very little to retrieve the failure. The life by John T. Morse in the "American Statesmen Series" is similarly defective, and the early biography by William H. Seward (Auburn, New York, 1849) entirely so. Only the Memoir (Boston, 1858) by the historian and one-time president of Harvard University, Josiah Quincy, gives a fair indication of the passion which Adams felt and the labor which he endured for the "increase and diffusion of knowledge among men."

The formal education of John Quincy Adams, secured in the intervals of travel and amidst the distractions of diplomacy, was almost entirely a literary one. He read the usual Latin and several of the Greek authors in their own languages. He cultivated a close acquaintance with the English and French poets, and he spoke the language of the latter fluently and accurately. "In truth," his father wrote, "there are few who take their degrees at college, who have so much knowledge." This was a claim as moderate as it was accurate in its emphasis; it was, in spite of his paraphrasing and poetizing, for his knowledge rather than his literary taste that John Quincy Adams was to become distinguished. In the same famous letter to Dr. Waterhouse, John Adams noted that in the course of the preceding year he and his son had spent their evenings upon Euclid, "instead of playing cards like the fashionable world." At Harvard, where the son now spent fifteen months and whence he graduated with honors in mathematics, the course which aroused his greatest curiosity and enthusiasm was one on natural philosophy. And the exact sciences, especially astronomy, were to be the objects of his keen interest throughout a life devoted to its last day to public affairs.

The eminence of John Quincy Adams in diplomacy and statesmanship so overshadows his scholarly interests that his labors for the advancement of science have been neglected. From the diary one gathers that he would have preferred a somewhat different assessment by the biographers of his services to his country and to mankind; and in this self-judgment we must concur. A reconsideration of his work is warranted on another ground also. Adams lived in the beginning of the scientific renaissance in the United States and touched that great movement at several points; and he recognized, as not all statesmen do, the importance of the services that science and statesmanship may render to each other. He once wrote that "The people of this country do not sufficiently estimate the importance of patronizing and promoting science as a principle of political action." That seems to mean that aid to the increase and diffusion of scientific knowledge is a function of government; and that government should operate upon the fullest obtain-

[1] Boston, Little, Brown and Company, 1932.

able knowledge of nature and human nature. Was not this a prophetic vision of the "brain trust"?

Public employment left Adams slight leisure for the prosecution of scientific interests. Once "in Mr. Bussey's garden in Boston" he served as the amateur helper of Nathanial Bowditch in the observation of a solar eclipse; and he kept in sufficiently close touch with astronomy to have confidence in his own judgment that Bowditch's "Navigator" was "a perfect treatise of practical astronomy." He had a part in the establishment of three observatories, at Harvard, at Washington and at Cincinnati. In the second place, his labors to assure the integrity of the Smithsonian bequest and for the creation of the institution constituted a national service. And his report to Congress on weights and measures has not ceased to receive the encomiums of scientists and publicists alike.[2]

The report upon weights and measures occupied Adams intermittently, from the Senate resolution of 1817, for a period of about four years; but this was not the beginning of his interest in the subject. Five years earlier, during the Russian mission, he was occupied with the French writers in the field, especially Paucton. He noticed that Paucton was led to study weights and measures from an initial desire to improve agriculture, but the accessory became the principal pursuit and he produced his "métrologie primitive." "This is too much the progress of all my studies," he adds; "but I shall never produce a metrology." He came closer doing so than seemed possible in 1812. The preparation of his report was "a fearful and oppressive task" made so by the fact that "all the power and all the philosophical and mathematical learning of France and Great Britain" had been expended upon the subject. What under the circumstances could one man do? He might have submitted an a priori opinion or a pro-forma state paper, prepared by clerks.

What Adams did was to study the subject both from its beginnings and its foundations; and to write, after careful research, a treatise historical and philosophical as well as practical. Its great distinction is that weights and measures are considered not only with reference to the nature of things but also to the nature of man, his abilities, habits and institutions. Adams attempts to trace the origins of these instruments from primitive times and early society. He compares the suitability of the decimal arithmetic of tens and tenths, with a binary or a duodecimal system, not merely for computation but for the practical handling of material things. He reviews the historic difficulty of establishing uniformity by law; notices that the power of a law is limited to the legislator's dominions, while trade and science are international; and concludes that the province of law over weights and measures is not to create but to regulate. He traces the legal history of weights and measures in ancient and in modern times, and in the latter he devotes special attention to England and France. He introduces at this point an extended and an appreciative history of the "sublime effort" of France to develop a decimal, that is, the "Metric" system which should be founded in external nature, scientific in construction and regular in form and nomenclature. When he came to consider the metric system as a practical instrument in commerce he was less appreciative; and he failed to consider it as an instrument in science except at its weakest point, the measurement of the circle and of time—features which had already been abandoned when he wrote. To understand his position we need only remember that to him the most important object seemed

[2] Report of the Secretary of State upon Weights and Measures. . . . February 22, 1821. 135 pp. plus appendices, 100 pp. House Doc. 109, 16th Cong., 1st Session (1820–21); also, Senate Doc. 119, 2nd Session of same Congress.

to be universality in the use of any system that might be adopted rather than its symmetry, its natural base or other ideal considerations; and that the metric system, though adopted by the government, did not come into general use even in France until after the date of his writing. His report has given comfort both to the enemies and the friends of the metric system.

The practical result of the report was nil; and in this there may be a fairly fundamental criticism, since its purpose was a practical one. Of its two main conclusions also, the second is now known to have been erroneous. Those conclusions, expressed in the form of recommendations to Congress, were: That for the present the English weights and measures should be retained without change, but that correct standards should be deposited with each State; and that Congress should attempt to secure a concert of nations as the only practicable agency for the adoption of a permanent and uniform system. The present wide use of the metric system has, of course, come about by a piecemeal process. But for most of the errors of opinion and some of fact in this celebrated document Adams can not be held responsible. We cite one or two. He did not know that Mechain had introduced an error into the measurement of the degree upon which the metric system is based and that its natural base is, therefore, a myth. He speaks of "the problem, hitherto unsolvable by man, of squaring the circle." It was in 1882 when Lindemann showed that no solution is possible. Again, Adams wrote: "For all the transactions of retail trade, the eighth and sixteenth of a dollar are among the most useful of our coins; and although we have never coined them ourselves, we should have felt the want of them, if they had not been supplied to us from the coinage of Spain." Such minutiae, interesting mainly as showing that the report has its own date written plainly upon it, serve by contrast to emphasize the industry and acumen which were required to produce a classic in American metrology by a Secretary of State.

On the day when Adams despatched his report he wrote in his diary that he might not again have time to prepare a scientific monograph. And although this fear was realized, his work as a promoter of science continued, for we should include under that title those who aid in the establishment of scientific institutions or who, in any way, to quote the words of James Smithson, further "the increase and diffusion of knowledge among men." Adams had a large part in securing the Smithsonian Fund and guarding its integrity. As chairman of the House committee to whom the matter of its application was referred he rendered valuable services for the whole ten-year period during which ideas were being matured, crack-brained schemes were warded off and public interest was aroused. Anxious both for the promotion of science and for the honor of the country and armed with only such faith in his followers as his grim political experience had inspired, Adams feared that the trust might be wholly dissipated by fraud or unwise investment or might be applied to useless objects. But if we mean to recall that his fears rose almost to the level of an obsession we must also remember that they were not groundless. All this can be studied in the diary and in the well-nigh exhaustive collection of documents bearing upon the founding of the Smithsonian Institution which was made by W. J. Rhees. Of Adams' efforts it may be said that they were directed to acceptance of the trust by Congress in the first place; against the inauguration of hasty, immature plans, which were proposed in numbers; and to bring it about that the funds should not be invested in state bonds as at first but should become a permanent obligation of the United States Treasury.

To be sure he did not get his astronomical observatory, "to be superior to

any other devoted to the same science in any part of the world." Secretary of the Treasury Spencer once told him it was because the whole country was laughing at his designation of observatories, as "lighthouses of the skies." But the Government did establish the Naval Observatory in 1843 and the Smithsonian Institution in 1846; and Adams' agitation had a useful effect upon both developments. It was just the time when the first permanent observatories were beginning to appear in the country. Winthrop and Rittenhouse and even Bowditch, who was not, however, primarily an observer, had none. In 1823 Adams had subscribed one thousand dollars for an observatory at Harvard, but the subscription could not be filled and the scheme failed. Less than a decade later and just as Adams entered upon the last phase of his life as a Representative in Congress, the building of American observatories began and increased until it became an educational and scientific trend, almost a fashion. Within a very few years of each other teaching observatories were established at Yale, at Chapel Hill in North Carolina, in Williams College and in Western Reserve near Cleveland and most distinctive of all in the new Philadelphia High School planned by Alexander Dallas Bache. In the West the center of the greatest interest in astronomy was at Cincinnati, and some work had been done by Dr. John Locke, who had even gone to Europe for information and instruments. The fruits of these efforts were gathered by Ormsby Mitchell who from the beginning of his connection with Cincinnati College extended his activities far beyond the boundaries of his professorship into work as a consulting engineer and a teacher of engineering. A newspaper of that day reports the arrangement by which "Each of the professors will be at liberty to receive pupils, in his own branch, as irregulars. Under this permission, Professor Mitchell will forthwith organize a class in Civil Engineering, of which his regular pupils will likewise be members. To afford opportunity for practice in this important study, the professor will be allowed a vacation of four months in the year, during which he will be in the field with his students, engaged in actual engineering."[3] To arouse the public interest in astronomy Mitchell resorted to lecturing, a form of instruction of which, as Lyell remarked, the Americans were very fond. The remark applied very well to Cincinnati, and Mitchell's lectures in particular were so popular that he raised the money for an observatory in that small western town. "If the public support, based on public interest," said Newcomb, "is what has made the present fabric of American astronomy possible, then we should honor the name of a man whose enthusiasm leavened the masses of his countrymen with interest in our science."

Ormsby Mitchell no longer needs an introduction,[4] but it was on June 22, 1842, that Adams noted in his diary: "Mr. Mitchell is a professor of mathematics of Cincinnati where he delivered last winter a course of lectures, he says, to three thousand persons, and he kindled such a passion for astronomy in that city that they have formed an astronomical society, with stock in shares of twenty-five dollars each, and have raised a fund of thirty thousand dollars to erect and furnish an observatory, for which purpose he is now going to England." Evidently Mitchell was himself quite a promoter and Adams did not like him at first. Besides the eloquent "he says" of the sentence quoted above the diary says: "There is an obtrusiveness of braggart vanity in the man, which he passes off for scientific enthusiasm, and which is very annoy-

[3] *Cincinnati Daily Gazette*, October 19, 1836.

[4] An account of him is F. A. Mitchel's "Ormsby MacKnight Mitchel Astronomer and General, a Biographical Narrative," 392 pp., Boston, Houghton Mifflin & Co. 1887. The spelling of the name used in the text above seems to have been the contemporary one.

ing"; and Charles Francis Adams, editing the diary, calls this "Scant praise for Mitchell"! A year later Mitchell was back to see Adams, this time at Quincy, with letters, resolutions and an urgent invitation from the Cincinnati Astronomical Society to lay the cornerstone of their new observatory and to deliver an oration on the occasion. During the autumn the seventy-six-years-old statesman may be seen at his desk attempting to compress a history of astronomy into an address. "My task," he wrote, "is to turn this transient gust of enthusiasm for the science of astronomy at Cincinnati into a permanent and persevering national pursuit, which may extend the bounds of human knowledge and make my country instrumental in elevating the character and improving the condition of man upon earth. The hand of God Himself has furnished me this opportunity to do good. But, oh, how much will depend upon my manner of performing that task!"

After a cold, uncomfortable journey of thirteen days, traveling alternately by carriage, railroad train, steamboat and canal-boat, he reached Cincinnati on the eighth of November (1843). The oration upon which he had been working for more than a month was yet unfinished; it was incomplete at one when he retired, and he rose at four to finish it. The ninth was a day of pouring rain and as he tried to speak at the cornerstone-laying there stretched out before him not a sea of faces but a concourse of umbrellas apparently floating on a sea of mud. The next day came the oration, which was well received. He remained for several days. Naturally the wealth, position and talent of Cincinnati crowded about him and fêted him—Judge Burnet, Thomas Corwin, Bellamy Storer and Nicholas Longworth, who, Adams learned, was the especial patron of the observatory. Back in Washington for the opening of Congress he wrote in his diary:

". . . The people of this country do not sufficiently estimate the importance of patronizing and promoting science as a principle of political action; and the slave oligarchy systematically struggle to suppress all public patronage or countenance to the progress of the mind. Astronomy has been specially neglected and scornfully treated." Was he thinking of the derision which greeted his "lighthouses of the skies"; or did he think that astronomy was scorned above other sciences because he had stood out as her special champion? The diary continues: "This invitation had a gloss of showy representation about it that wrought more on the public mind than many volumes of dissertation or argument. I hoped to draw a lively and active attention to it among the people, and to put in motion a propelling power of intellect which will no longer stagnate into rottenness. I indulge dreams of future improvement to result from this proclamation of popular homage to the advancement of science, and am willing to see my name perhaps ostentatiously connected with a movement to which I so long and so anxiously strove to give an impulse in vain."

Is it too much to ask of a biographer that he shall read the great diary, extensive as it is; and, having read, that he shall duly ponder the many pages upon which the scientific interests and activities of John Quincy Adams are written at large? Having done so, he will recognize in Adams a scientist-statesman who saw that it is an important duty of government to patronize and promote the increase of knowledge among men. If now such a biographer will have the vision to see and the courage to present the facts as they are, the results should be salutary even though, comparatively, the glory of the Monroe Doctrine might be dimmed a little. Adams might say to his biographers, as Cromwell is reputed to have said to his artist: "Paint me as I am."

PARASITES, FRIENDS OF MANKIND

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A FEW years ago I attended a lecture in which the speaker prefaced his remarks with the statement, "Nobody loves a parasite." This is undoubtedly true. Not only do parasites fail to awaken affection in our breasts but, I fear, we are inclined even to despise such of our fellow organisms as have adopted this method of gaining a livelihood. The inference is, of course, that we consider ourselves to be, in some respects, superior to parasitic forms of life.

When we view the matter impartially, however, we can hardly stigmatize a parasite, which obtains all its nourishment from a single host, as a more serious biological offender against its fellow organisms than are catholic predators, such as ourselves.

Man, beyond a shadow of doubt, is the most abhorrent exploiter of all forms of animal life that the earth has produced. He searches the entire surface of the globe, the depths of the ocean and as far upwards as he can reach towards heaven in order to obtain victims that will satisfy his predatory appetites.

Members of nearly every phylum in the animal kingdom find their way into the insatiable stomach of man. The few that escape do so because he does not relish the flavor of their flesh or because, while living, they appear to him to be somewhat repulsive. We eat oysters with avidity, provided we obtain them in a month that contains an R. Few of us, however, have more than a hazy idea of the manner in which oysters pass their days or even of the significance of that qualifying R. In order that we may continue to enjoy the gustatory pleasure evoked by these slippery bivalves it is perhaps as well that we continue to make our first acquaintance with them in company with cracked ice and labelled, "60¢ a pint."

On the other hand, we are all more or less familiar with caterpillars during their lifetime. In this stage of their career the majority of us consider them to be so repulsive that the bare idea of eating one is accompanied by an involuntary shudder. The old riddle, "What is worse than finding a caterpillar in the apple you are eating?" with its answer, "Half a caterpillar" makes too universal an appeal to need further comment. This, despite the claim that caterpillars, when properly prepared, are very palatable and of undoubted nutritive value. Somehow I feel that man, the predator upon mammals, birds, fish, amphibia, crustacea, arachnida and mollusca, falls short in his glory as the consumer, par excellence, of his fellow creatures by this unfair discrimination against insects.

Still more appalling than is our widespread predatism are some of the methods whereby we daily exploit our more or less distant relatives. What term would we invent to describe any animal, other than ourselves, which consistently removed new-born young from their mothers and, thereafter, stole for its own use the almost sacred maternal fluid that is produced solely for the nutrition of their helpless offspring? Such behavior would be considered as scarcely an approved topic for conversation in polite society.

Some of us prefer our eggs as omelettes, as a soufflé or merely "sunny side up." However we may disguise them, we consume almost daily the un-

formed young of a fellow traveler along one of the divergent paths of life.

These examples should serve at least to indicate that parasitism is a very mild form of exploitation as compared with the types of predatism that are practised regularly by the most "humane" among mankind. If, in addition, you care to contemplate the refined cruelty of cramming and of paté-de-foies-gras I think you will agree that, in the whole realm of nature, man, least of all her diverse creatures, has cause to point the finger of shame at any other form of life which lives, in any manner whatever, at the expense of its relatives.

It is not, however, my purpose to blacken the face of man in comparison with strictly parasitic forms of life. It would not, indeed, be difficult to show that he himself evinces many tendencies in this direction in addition to his other crimes. Rather, taking man as he is, I wish to establish the fact in your minds that we have cause at least to be grateful to many parasites. More than that I will not ask. Love is, perhaps, too intimate an emotion.

The meaning of the word "parasite" is extremely vague. Restricted originally to a class of human society, its application has been widened to include a most heterogeneous variety of biological relationships. What exactly do you or I mean by a parasite? Any standard dictionary gives six or seven alternative definitions. There are several varieties of social parasites and still more numerous nutritive parasites. To the biologist there are many more types than those that find their way into a dictionary. If we consider but one form of life, namely, insects, we find that they exemplify several different degrees of nutritive parasitism.

First of all there are those which spend their entire lives feeding on the surface of a host animal. Lice are examples. Since they never enter their host they are termed "ectoparasites." Others, as larvae, are true endoparasites. These live entirely within a host. They may or may not feed at all when, as adults, they subsequently live an independent life. Common examples are the warble-flies of cattle.

A little further removed towards independence are the so-called parasitic wasps or ichneumonids. The majority of these live, during their larval life, within other insects. As adults, many feed exclusively on pollen and nectar from flowers. These, certainly, are less truly parasitic than are lice. Some writers prefer to classify their activities by the non-committal term of "parasitoid."

The ill-famed bedbug imbibes from the nearest victim at mealtimes and then retires to its own quarters. Should these be included in the category of parasites? If so, shall we draw the line between them and the flea which, when immature, finds its food on the ground and only when mature relishes a meal of blood? It is probable that the majority of people would consider the flea to be truly parasitic, despite its virtuous early life. If then we include fleas shall we widen this term by the addition of mosquitoes? As larvae these insects feed exclusively on material of vegetable origin. Even after they have reached maturity the bulk of their nourishment is obtained from the same source. Every male dies as he has lived, a strict vegetarian. All that a female demands from her distant relatives is an occasional draught of blood. This appears to be necessary for the development of her eggs. For the rest of her career she, too, sips nectar from flowers by the side of her consort.

When such a diversity of relationships are called by the same name, and when we consider that a dozen additional types of exploitation could be added if we seek elsewhere, it is no won-

der that the word "parasite" has a somewhat nebulous meaning. In its strictest sense it would seem that the term, when applied to nutritive relationships, should be restricted to any organism that obtains all its nourishment from a single host animal. All others are, in reality, types of predators. Since, however, all are variations of the same phenomenon we need not, for the purposes of this paper, draw very hard and fast lines between parasites and predators.

The true parasite rarely kills its host in obtaining its dole of nourishment. It is, obviously, a remarkably bad stroke of business on the part of a parasite to destroy the source of its daily rations. It is even bad business to make the host aware of the fact that it is being exploited. From a biological point of view the most successful parasite is the one that can obtain its nutriment with the least discomfort and detriment to its host. The mosquito which obtains her draught of blood from your neck without your being aware of the robbery stands a better chance of raising a family at your expense than does her cousin whose pilfering is proclaimed by a vicious stinging sensation.

The bites of the so-called "wild" mosquitoes, which inhabit sparsely peopled regions, are far more painful than are those of their "domesticated" relatives, which inhabit those parts of the earth that have been densely populated for many human generations. The present inhabitants of the latter regions owe a debt of gratitude to their forebears who, through ages of unremitting slapping, have selected strains of mosquitoes that obtain food with the minimum of discomfort to their hosts.

We, in our generation, do something for posterity every time we kill a particularly vicious mosquito and ignore the activities of her milder mannered sisters. To a trifling degree we throw the balance for survival in favor of strains that cause the least annoyance to man.

The relentless laws of evolution continually weed out as unfit to compete for immortality, through the medium of their descendants, those strains of any parasite that are less considerate of the welfare of their hosts than are their near relatives.

A perfectly adapted parasite causes no appreciable damage to its host apart from draining from it a modicum of nutriment. This stage of perfection, probably, is rarely attained. When it is, some writers term the relationship thus established between host and parasite "symbiosis"—living together. Many insects, among which the most familiar to us is the ubiquitous cockroach, carry from generation to generation colonies of bacteria embedded deeply within their bodies. A certain number of these are transferred from the parent's body to every cockroach egg long before the latter is laid. What effect these bacteria have on the lives and the happiness of cockroaches we are unable to say. Every cockroach contains them, and we know of no way of removing them. We do know, however, that certain hosts obtain a direct benefit from their ever-present parasites, and that they ultimately become dependent upon them for their very existence. When this is the case we pass from parasitism, through symbiosis, to "mutualism," or the interdependence of the two organisms. Such, for example, is the relationship between white ants and the luxuriant fauna of protozoa which invariably inhabit their alimentary canal. These can be killed, without otherwise affecting the white ant, by subjecting the latter to an atmosphere of oxygen under pressure. Deprived of its one-time parasites a white ant can no longer digest its normal diet of cellulose and it dies of starvation in the midst of plenty.

It is even postulated that our own red

blood corpuscles may be the outcome of an invasion of the blood of our distant ancestors by parasitic protozoa. These examples, to which many others could be added, are of considerable biological interest. They show that parasites can, if given a sufficiently long period of adaptation to their hosts, be modified into most valuable companions. As is the case in many walks of life, it is the novices that cause the greatest havoc.

Only under most exceptional circumstances can predators prove to be temporarily advantageous to the welfare of their victims. Man, by protecting his intended victims from other forms of life that desire to share the feast with him, may prolong the lives of some of his domesticated animals. Loud, however, are the complaints when he errs by stretching the span of life beyond that of gastronomic perfection.

I have yet, however, to vindicate my premises to the effect that parasites are actually the friends of mankind. I propose to attempt so to do, though I anticipate that few of you will agree with me in my efforts to show that our own specific parasites are more beneficial than otherwise. In what I am about to say I would ask you to think of mankind as a race rather than as a collection of individuals. To the individual his parasites are naturally unpleasant and deleterious. Attempts to consider them otherwise have not met with marked success. Hermits of old believed with religious zeal that all things on earth were created for the good of man. "All things" necessarily included human parasites. These were satisfactorily fitted into the creed by accepting the dictum that they were created to mortify the flesh, which is the sinful part of man. Clothed in their unwashed and overpopulous garments these ascetics had ample opportunity to praise God for the activities of His humble workers. Fortunately for our bodily comfort, the religious attitude towards parasites is less heroic at the present day. We have no hesitation in employing every means at our disposal to protect our bodies from all kinds of marauders.

When, however, we consider mankind as representing a mammalian species, with all the attributes of other biological organisms, we may discover, in the parasites of his race, a valuable asset in maintaining some of his most cherished ideals.

I need hardly remind you that all forms of life over-reproduce. To this general biological law man is no exception. Nearly 150 years ago Malthus showed that, under favorable conditions, human populations tend to double in numbers every 25 years. Who among us desires to live under any but favorable conditions? This rate of increase was exceeded in the early years of the exploitation of our own continent, at a time that preceded nearly all the more important life-saving and life-prolonging discoveries. It is obvious, however, that the population of any part of the world can not continue to increase indefinitely. Theoretically it can do so only until such times as its demands equal its supplies. Thereafter it must remain moderately constant. This point being reached, as Malthus pointed out, the checks to further increase come under two general headings—preventive and positive.

We need not dwell for long on preventive checks. These have undoubtedly been powerful in the past in crowded communities. Some people believe that they will become increasingly effective and that they will solve the entire problem of population stability. Such a solution is, of course, biologically unsound, and is the first step in the direction of race deterioration and possible extinction.

From the far distant and misty past, when life first became a reality on earth,

down to the present day, all living things have, with reckless abandon, produced a continuum of generations, in every one of which the individuals have been far in excess of the numbers that can survive. From this superabundance nature, as unremittingly, has made her selection of a small minority that she judges to be fit to fulfill their destiny of continuing this over-reproduction. The vast majority she sweeps into the discard. Their lot is to perish miserably, or otherwise, provided their demise be expeditious. By this relentless persecution, only, has nature improved her diverse forms of life and has brought to perfection their various adaptations for competing to-day with their all-too-numerous relatives. Man is but one of these many competitors. Can he afford voluntarily to set aside the factor that has been paramount in bringing him to, and maintaining him at, the physical and mental level he has reached? When man ceases to over-reproduce the laws of race improvement will cease to operate in so far as he is concerned. He will stagnate, from an evolutionary point of view, in a world in which all other forms of life are pressing forward to greater and more varied destinies.

I am, however, of the opinion that man, in common with his less intellectual relatives, will continue to over-reproduce and therefore to progress as a species at the expense of those individuals in each generation which are least fitted to be men.

Without further consideration of preventive checks we can turn our attention to the positive checks—those which remove individuals after birth, but before they have contributed their full quota of offspring to the overnumerous ranks of the rising generation. I think most of us will agree that, in the past, these have been emigration, starvation, disease and war. Of these starvation, or the fear of it, has played a prominent part in engendering the other three.

The world over, human populations have been frequently in danger of reaching saturation point, till one or other of these checks temporarily relieved the situation.

The saturation point of many of the more densely populated regions of the earth has been greatly increased by the discovery of areas that were more thinly populated because they were less expeditiously exploited. Numerous emigrants to these regions have relieved the pressure at home and, in addition, they have effectively exploited the possibilities of the land of their adoption. Here they can produce far more of certain necessities to life than they, themselves, require. The development of rapid world-wide transportation enables them to pour their surplus into their native land. With this influx of supplies the saturation point of these countries has increased by leaps and bounds. It now far exceeds the possibilities of their own resources. The discovery of America by white men has increased the world population by possibly twice as many individuals as can be numbered among the 180 millions who inhabit it.

In the history of the human race this can, however, be but temporary. The day must come when all humanity will weep with Alexander, and with far more reason, because there are no more worlds to conquer. Already we see the first signs of this on our continent. The rapidly increasing progeny of earlier arrivals are already putting up the bars against their relatives in overcrowded countries who would follow in their footsteps.

With the diminution of this outlet for surplus population the day draws appreciably closer when man will have reached his mean of maximum abundance over the entire earth. He can no more escape this destiny than can any other form of life. Wars, disease and starvation have combined in putting off this day. Man is setting his mind as

never before to mastering all these checks to this steady advance towards the inevitable. What will be the result if he succeeds in his endeavors?

Whatever the size of the family, once the mean of maximum abundance is attained, an average of two only can survive. Darwin made this abundantly plain many years ago, but man, in various parts of the world, continues to struggle against this law. Among the Chinese, in a land the population of which had reached its maximum centuries ago, despite many wars, much disease and appallingly wide-spread starvation, every man still feels that he must have at least twelve children in order that two may survive to do homage to his old age. The fate of the ten who are doomed to perish at an untimely age appears to us to be tragic. They merely exemplify nature's universal method of procedure; over-reproduction in order to assure adequate survival.

Fluctuating as is the mean of maximum abundance that the laws of nature allow to any species, a marked increase during any abnormally favorable period, be it long or short, inevitably spells additional misery to all succeeding generations till the population is, once more, reduced to its proper level. During this readjustment period nature, more drastically than at other times, weeds out for survival the few that are the best equipped to vanquish their most implacable rivals—brothers, sisters and cousins—for all of whom there is no longer room on earth. The more prolific the animal, the more drastic is the mortality in every generation. The majority of insects lay 300 eggs. Since, of the insects that should hatch from these, an average of two only can survive, 298 (*i.e.*, 99.3 per cent.) must perish without reproducing in order to maintain their *status quo* with other forms of life. At times, nature, for a period, relaxes her persecution of some insect and allows the mortality to drop to, let us say, a mere 90 per cent. It is not long thereafter that man cries as did the prophet Joel, "That which the palmerworm hath left has the locust eaten; and that which the locust hath left has the cankerworm eaten; and that which the cankerworm hath left, has the caterpillar eaten."

But nature never fails to take her revenge at the expense of future generations. She raises her harvest to 99.9 per cent., or higher still, if needs be, in order to force her upstart offspring back into the niche that she has prepared for it by her infinitely slow but perfectly adjusted laws of maximum survival.

These laws apply, with no less rigidity, to man. Slowly as he may increase his numbers as compared with his more lowly relatives, the difference is only in degree, not in kind. If in the present generation the total world population is increased, future generations must pay the bill.

The statement that all men must die is axiomatic. To this must, however, be added the corollary that a large percentage must do so before they arrive at the stage of parenthood. The grim harvester of the childless is implacable. As the vacant spaces of the world fill up he becomes increasingly insistent in his demands. Struggle as man may to avoid the inevitable, there is no escape. One or other of the pruning knives must fall. Which of these, starvation, war or disease, is the least detrimental to the future development of the human race? To this trio we might add, with increasing significance, a fourth—namely, "accident." The auto is already assuming a prominent rôle in holding populations more nearly to their *status quo* in many parts of the world.

Starvation, war and disease. All have had their share in the past in regulating human populations. All will, doubtless, continue to do so in the future. Is it

not as well then for us to consider each in turn and to discuss its relative merits? Each by itself is ghastly. One, however, that is the least so, or one that shows some redeeming feature in that its operation tends to improve the caliber of the survivors, is a veritable haven of refuge from its more devastating competitors. Our effort at the present time is, quite naturally, to avoid all three of them for ourselves and for our children. We are willing to let future generations decide for themselves to which they will submit when nature presents her bill for the overdraft. In this endeavor mankind reveals his fundamental selfishness.

Among primitive races, dwelling in confined areas, starvation has doubtless been a potent pruning knife for trimming the family tree. It must be borne in mind, however, that this is nature's last resort, which is employed only when all else has failed. Whole nations have, in the past, been decimated by starvation. Can any one imagine a similar occurrence among modern "civilized" communities? Could you postulate a democratic nation content gradually to starve when neighbors have ample? Commercial rivalry may be a somewhat distant forerunner of actual starvation. Who would deny, however, that this has been the cause of many recent wars? The desire for adequate nourishment is so deep-seated in every animal that no biological urge can arouse enmity more rapidly among fellow creatures than its denial. I believe that starvation will never again play a direct and widespread part in maintaining the *status quo* of populations. It will always be preceded or accompanied by war, whether in the form of individual killings, revolutions or trumped-up wars of national honor against neighbors. Democracy has given the hungry an equal voice with the well-fed in expressing his opinions and, through the medium of the vote, in enforcing them. Whatever might be the ultimate effects of starvation on the race they are subservient to those produced by its consort, war.

War is distinctly unpopular in the minds of the majority of people at the present time as an acceptable means of removing surplus populations, and rightly so. In the past it has been man's most favored method of regulating population difficulties. It has appeared to be the most logical means for adjusting the difficulties that arise when demand is somewhat in excess of supply. It may be claimed that many wars in the history of mankind have not had their origin in actual or imminent shortage of supplies. There can, however, be no argument but that every war has resulted in the reduction of population. They have, to that extent, served their purpose and have obviated the necessity for later wars in which self-preservation would have been the sole motive.

War as a check to overpopulation is, however, more biologically unsound than is restriction of birth. Truly it has been said that those who live by the sword shall die by the sword, if this be interpreted as applying to communities and not necessarily to individuals. No community, which in the interests of self-preservation makes war on its neighbors, would hazard the risk of sending its weaklings, either physical or mental, to bear the brunt of the fray. The best they have in manhood goes forth, many of them never to return. To their weaker brethren falls an undue share in assuring race continuity. It is inevitable that this type of selection, when indulged in frequently, must lead to race deterioration. The day will surely come when the community, deprived not only of those who lived by the sword, but also of those who would have been their progeny, will die by the sword of a more favorably selected strain of neighbors.

Although there is to-day an increasing realization that war is unethical, uneco-

nomical and that it outrages all principles of beneficent race selection, I, for one, can not believe that it is a passing phase of human activity. Human nature can not be remodeled in a single generation, and only very slightly in a hundred. Fashions, admittedly, change with every season. Twenty years ago men who, for one reason or another, did not reveal any eagerness to go out and fight were liable to be decorated with a white feather at the hand of a feather-brained girl. How fashions have changed in twenty years! Fashions are, however, only a veneer that but ill disguises the true nature of the object beneath. From the dawn of life on this earth till to-day man, or his ancestors, has fought his fellow men for his very existence and survival. Because your forefathers and my forefathers struggled ceaselessly against, and vanquished, the potential parents of myriads of other men and women, we and not they, inhabit the earth to-day. You and I are the product of aeons of bloodshed and hatreds. We may not feel very grateful for the legacy, but the parent who readily abandons her offspring in the interests of her neighbor's will never make a very powerful human appeal.

In the year of grace 1934, mankind, as he completes his million to the nth generation of internecine warfare, proclaims: "Every one of my myriad ancestors who, because he fought, survived to reproduce his kind was in the wrong. The world should have been peopled with the progeny of those who died at their hands, and I have no right to be here. Beginning with my million to the nth plus one, generation I declare myself purged from my hereditary taint. I am henceforth reincarnated. Incidentally, of course, all my neighbors are reincarnated also."

This is an excellent resolve. All success to his efforts! Surely, however, in such a quest he will need powerful friends. He looks to be rather a poor lost mite as he carves out his new destiny in a universe where brother has fought brother incessantly from the dawn of life to the present day in which amoeba still ingluves amoeba and the elephant trumpets over his dying rival.

Where, in such a world, is he to find friends who will aid him in his high resolve? Only, it would seem to me, in those allies that are always on hand to reap for him the supernumeraries of his kind, his own parasites, his diseases. Provided these supernumeraries are brought into the world at the same mad rate that they have been in the past, and evolutionary progress demands that they must be, somewhere must be found the harvester of the immature. Emigration and starvation have nearly run their course in making room for those who are left behind. Man, and may God prosper his resolve, is determined never again to lay his sickle to the superabundant harvest. Already he contemplates placing it aside and is drawing plans whereby it may be beaten into a cradle-rocker. Rather wisely, however, he is not putting his plans into effect just yet but is keeping it in the attic till he is assured that his neighbors are like-minded. A cradle-rocker is a poor implement to seize should the cry go forth, "Harvest or be harvested!" Have we sound reasons for believing that this cry has been heard for the last time on earth? For how long can man hope to live up to his new-formed ideals? The answer, I submit, depends chiefly upon the activities of his friends and enemies, his own parasites. If, with relentless insistence, they garner a sufficiently abundant harvest of the childless to assure that there is room for all that remain, then, and then only, it would seem to me, can man hope that neither he nor his neighbors will succumb to his hereditary instinct to fight for his own preservation and for that of his children.

This may appear to be a ghastly alternative to war. Surely it is infinitely preferable. Association with those who are struck down with disease tends, at all events, to bring out the best in human nature, sympathy and self-denial. Certainly not the adjuncts of war, enmity and brutality. War takes from us of our best, disease those whom we pity the most because they were not so blessed in physique as are the common run. Of course there are tragic exceptions. There are also exceptions in the case of war, but the general tendency of disease is to improve the race; that of war to deteriorate it.

There is no denying that war and disease have been the major regulating factors of human populations in the past. Provided the number of births continues to be in excess of deaths from accident or old age one or both must remain in office. For my own part I can not visualize a world (in which there is a measure of individual freedom of action) in which there is a perfected medical service and an absence of armies. Such concepts are mutually antagonistic, and no world can be, for long, large enough to contain both of them.

Bound as we are to fight those invidious enemies, the parasites of the individual, they yet constitute the most potent friends of mankind as a race in his groping towards brotherly love.

All honor to those who burn the midnight oil, who impair their own health and who imperil their very lives in their efforts to wrest their fellow men from the scourge of disease. Theirs is perhaps man's most lofty ideal, but, pray God, for the sake of mankind, that they be not too successful in their efforts.

Many of you may even yet feel that I have failed utterly to prove that parasites are, or ever could be, friends of mankind. If so, I regret that my proof has failed to convince you. It will be necessary, therefore, for me to bring forward conclusive evidence to the effect that you and I exist on earth simply by the grace of parasites. I would draw your attention for a few minutes to the debt we owe to those parasites which hold in check the numbers of our most insistent rivals—apart from our fellow men—the plant-feeding insects.

Ages before the ancestors of man had escaped from the ocean, mother of all life on earth, the dry land already teemed with insects.

It is probable that it was from the tidal shores of some Devonian ocean that a trilobite-like creature, for the first time in the history of animal life, not only succeeded in living out of water, but completed the emancipation of its descendants by depositing eggs that hatched without submersion. This lonely creature, ancestor of all insects, donated to these descendants all the dry land of earth from pole to pole. Overcrowded as was the ocean, there were as yet no competitors for the luxuriant vegetation that covered the vast mountains, valleys and plains of earth. Surely this insolent speck of animal life, by invading an entire new world, would be swallowed up in the very enormity of its undertaking.

Armed, however, with a good digestion and a superabundant fecundity it was not long—only a few millions of years—before its descendants were seriously overcrowding each other in every part of the earth that was habitable to them. By the carboniferous age they had acquired wings the better to escape from each other and to seek pastures new in which they might browse in peace. Even this phenomenal aid to rapid dispersal could counteract for but a time the menace of their own fecundity. The time must surely arrive when the demands of the insect population, in various parts of the earth, would be in excess of the vegetation that it could produce. By its very success insect life

was threatened with extinction, until this life took advantage of its own excesses. Certain groups of insects became adapted to feed upon their plant-feeding relatives. At first there were simply scavengers or predators, but later many of them developed into true parasitoids.

From that time onwards insects have never regained their status as the dominating form of life on earth. Popular magazine articles to the contrary, I, personally, believe that the age of insect ascendancy on earth has passed. It was terminated by the insects themselves when they learned to parasitize each other. Not only did this terminate for all time the possibility of any further marked increase in insect populations, but it made room for the safe invasion of the dry land by the ancestors of man and his relatives.

A marvelously adjusted balance was soon established between the abundance of those insects which still fed on vegetation and those which, as parasites, became dependent upon their numbers for their own numerical strength. This balance holds to the present day. It is not, however, a matter of very great surprise that there is still an intense rivalry between these one-time lords of creation and their comparatively recent competitor, man. Man is now beginning to realize that the most effective weapon he can employ in combating them is to call to his aid those all-powerful allies, their parasites.

Both the plant-feeding host insects and their parasites are capable of prodigious over-reproduction in every generation. Both, however, are held to about the same number from year to year on account of the abundance or the scarcity of each other. The host insects are prevented from increasing by the annual decimation of their youth by the parasites, and the latter fail to increase their numbers because they do not allow the host to become sufficiently abundant to provide dwelling places for any increase in their own families.

Vagaries in the climate of any year may, however, favor an unusually large survival of either host or parasite. If it be the host that is thus favored this automatically provides the parasites with opportunities to raise abnormally large families. The result is that the next generation of host insects have an unusually large number of parasites seeking their destruction.

We are all more or less familiar with outbreaks of plant-feeding insects. For a few years some species of cutworm or grasshopper gives a limited demonstration of its ability to increase in numbers. During this period we, their inevitable rivals, feel that we are most unrighteously cheated out of more than the 10 per cent. of the earth's produce that we still concede to our declining foes. Were it possible for a cutworm outbreak of world-wide extent to continue for half a dozen years, and for the initial rate of increase in population to be maintained throughout this period, there could be but one outcome in so far as man is concerned. He would be starved out of existence, unless perchance he discovered that he could satisfy the requirements of his body by eating fresh cutworms in summer and preserved ones in winter.

Insect outbreaks, however, do not last indefinitely. Parasites are not slow to take advantage of the increased number of their host in order to reveal their own powers of increase. By the end of the second year of an outbreak, at the latest, myriads of cutworms fail to turn into moths that normally would have laid their 300 cutworm-producing eggs. Instead they give rise each to a parasite, which is loaded with 300 cutworm-destroying eggs. Under such circumstances it can be but a matter of a few years before the outbreak has been terminated by them. Thus do man's allies and friends, parasites, prolong his lease of life on earth.

It is true that this relationship between the abundance of host and parasite is complicated by many interacting factors. Possibly it will never be thoroughly understood by man. We can, however, grasp its most salient characteristics. Furthermore, we can utilize this relationship to our own great advantage.

In 1843 a French naturalist, de Poitiers, made the then original suggestion that native predatory beetles could be utilized by man for the control of caterpillars in gardens. This was hardly a practical suggestion. We now know that it is only by importing parasites from distant countries that we can expect to obtain a marked benefit from interfering with their activities.

It was not until nearly 1900 that the exportation of insect parasites from one country to another had been proved to be an effective method in insect control. To the United States belongs the greatest credit in developing this, the most logical method for holding the numbers of injurious insects in check. The reason for this is, to some extent, due to the fact that here, more than in any other country, alien insects seriously menaced not only many phases of agriculture but, in addition, the natural beauty and the forest reserves of the entire continent.

Early arrivals from Europe soon discovered that the Indian had not been an expert in developing the fruits and other vegetation that were native to America. If they desired "improved strains" they had to import them from their home countries. This led to the extensive importation from Europe and elsewhere of fruit trees and bushes, of ornamental trees and shrubs and of the roots or seed of herbaceous plants. Unfortunately, on some of the vegetation that was brought to this country, there were occasionally a few eggs or other developmental stages of insects that normally fed upon it in the home country. All too many of these were able to continue their development in the new land. At the time no one realized the menace of this handful of undesirable aliens, and could hardly foresee that they would prove to be a greater detriment to agriculture and to fruit production in America than were the countless millions of insects that already inhabited the country. Never in Europe had insects, such as the codling-moth, the cabbage-butterfly, the gipsy-moth, the larch-sawfly, or the more recently imported corn borer, to mention but a few, done a fraction of the damage that they proceeded to do in eastern America. Not only did they ruin many of the imported plants, but, increasing in leaps and bounds, insects such as the larch-sawfly and gipsy-moth began the utter destruction of any native trees that met with their food requirements.

In Europe the larch-sawfly had been recorded as a somewhat inconspicuous insect that was occasionally found feeding on larches. There all interest ceased until it was accidentally imported into the Arnold Arboretum in Boston in 1882. In 1883 it had already spread to Canada. The following is a quotation from the report of the Dominion Botanist, Dr. W. Fletcher, which was made a few years later: "After three to four years of being stripped, the larches over millions of acres, and practically over the whole of eastern Canada, were almost wiped out. With this large destruction of its food plants the insect practically disappeared."

The history of the gipsy-moth in America since 1896, when some half dozen of its caterpillars escaped in the vicinity of Boston, is too well known to require a detailed repetition here. It will suffice to recall that, during the next forty years, their progeny devastated millions of acres of forest and ornamental trees. At the end of this period it appeared that, despite everything that

could be done, the brains of man were outmatched by the fecundity of the gipsy-moth. There was grave danger that it might gradually devastate the whole of the continent with the exception of northern Canada which, fortunately, lies beyond its climatic range.

Why should the gipsy-moth prove such a scourge in America? It was well known to those of us who passed our youth in Europe. There, it was just "one of the insects" of woodlands of which there were occasional outbreaks which might last for a year or two and then subside. Why, then, in America was this outbreak permanent until such time as it subsided simply because the caterpillars had destroyed everything on which they could feed? The answer, of course, is that, though the gipsy-moth had found a home in the New World, none of the parasites which normally live at its expense in Europe had managed to emigrate with it. By 1913, however, man had mastered the gipsy-moth, but his mastery was attained only through the medium of parasites.

When, after overcoming obstacles which, at times, appeared to be insurmountable, he succeeded in introducing from Europe several of its most important parasites the end of the gipsy-moth's reign of terror was in sight. It is true that the infested area continues to increase despite all direct efforts on the part of man to prevent it, but close on the heels of the caterpillars will follow its relentless parasites, whose sole business in life is that of decimating their numbers. Despite this increase in invaded territory the status of the gipsy-moth is changing from that of an unmitigated scourge to that of an additional, albeit unwelcome, insect that inhabits the woodlands of America. This is possibly the most decisive victory that man has won over his age-long rivals. It will be seen, however, that this victory was won, in reality, by parasites that man called to his aid.

More recently a portion of Ontario and of a few neighboring states has been invaded by the European corn borer. This insect, if left to its own devices, threatened to ruin the entire corn-growing industry of North America. Vast sums of money have been expended on mechanical methods and for poisons in an effort to prevent it from spreading to territory that is at present uninfested. Effective as many of these have proved to be, they are but temporary expedients; expensive and laborious stop-gaps that serve a valuable purpose until the parasites which have been hurried from Europe will assume the permanent rôle of holding down the population of the corn borer. Parasites, of course, will never exterminate the host insect, but, once they are established, their numbers will steadily increase at its expense till no further increase in the population of either is possible. Although the plant-feeders may still be present in sufficient numbers to cause serious damage there are henceforth definite limits to their destructiveness.

A somewhat different employment of parasites is now being attempted on the Canadian prairies. In recent years the wheatstem-sawfly has ruined thousands of acres of wheat. This is a native insect. It is not, therefore, in the same class as is an imported pest. Before the days of agriculture it was a rather rare insect on the prairies. How are we to account for its phenomenal increase? The answer is that we have imported a foreign plant which this sawfly inhabits in preference to its native home. The sawfly lived originally only in the stems of native grasses. Now it lives in the stems of wheat.

Parasites that attack its grubs in grass-stems fail to do so very effectively when they inhabit wheat. Thus, by a somewhat unexpected route, the sawfly has escaped from its parasites, and man, as is usual under such circumstances, is a heavy loser. What can be done in a

case like this? We know of no very satisfactory method for forcing the recalcitrant Canadian parasites to attack the sawflies that inhabit European wheat. In Europe there is, however, a close relative of our American sawfly that also lives in wheat. It never does very much damage in England, because there it is in a state of equilibrium with a number of parasites which attack it in wheat stems. If we were to bring some of these English parasites to Canada would they attack our Canadian sawfly grubs in wheat stems here? Could they reduce its population to the insignificant numbers of its English relatives? It is too early to hazard an answer to these questions. Parasites have been brought over and have been liberated here. Some of them have succeeded in surviving our severe winter, but we do not, as yet, know how successful they will be.

I have selected a few somewhat spectacular examples of the use to which man is learning to put parasites. This art is as yet in its infancy. However successful the results may be, they are of infinitely minor importance when compared with the debt we owe to the ever-present parasites of our thousands of native species of plant-feeding insects. The majority of these are so rigidly held down to small numbers year in and year out that we never even trouble our heads about them. Under certain combinations of climatic conditions a few of them, unfortunately for us, manage occasionally to elude, to some extent, the attentions of their parasites. When this occurs the entomologist becomes, for the time being, a person of considerable importance. People have even been known to listen to a complete ten-minute address by him on the radio, under the stress of the situation.

During these "outbreaks" losses may run to several millions of dollars in addition to the large sums of money that are expended on control measures. Usually only one, or at most two, insect species are concerned in an outbreak. Picture the situation, however, if all species of plant-feeding insects were liable to occur in outbreak numbers on account of some vagarity in our climate. The fact that our native parasites do keep down the numbers of practically all of them, year in and year out, despite every variation in climate, doubtless reduces your respect for entomologists, reduces the number of highly paid positions for entomologists and has given me time to prepare this paper which I am inflicting on you.

Despite these manifest failings, I still claim that parasites have every right to your respect and that they are, more than otherwise, the friends of mankind.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

ELECTRON OPTICS

By Dr. C. J. DAVISSON

BELL TELEPHONE LABORATORIES, NEW YORK, N. Y.

In the olden times when the filaments of incandescent lamps were exposed to public view in bulbs of clear glass, it was possible to make quite an interesting experiment with a magnifying glass. By holding the glass in the right place an image of the filament could be formed on the wall of the room—a small bright one with the glass held near the wall, and a large pale one, which jumped about a good deal, with the glass held near the lamp.

It is quite well known, of course, how these images are produced, but that won't stop me from telling you. It's done by refraction. When a beam of light passes from air into glass its direction is changed—it is turned through a certain angle and the angle isn't always the same. It is zero when the beam comes straight at the glass surface and gets larger as the light comes at the surface more and more obliquely. So we have a way of turning a beam of light. We hold a piece of glass, say an inch thick, across a beam of light—if we hold it straight across, the light goes straight through without turning. If we turn the glass so the light meets the surface obliquely, then the beam is turned as it passes into the glass. It is turned in the same direction the glass has been turned, only not so far. But then when it comes out the other side it gets turned back again—so that all that has happened really is that the beam has been moved over a bit. But now suppose that instead of a plate of glass we have a wedge-shaped piece—the sides not parallel—then the two deflections won't just compensate one another as they do when the sides are parallel, and the beam will leave the prism, as a wedge-shaped piece of glass is called, in a different direction. It will have been deflected away from the thin edge of the wedge. Now, you see, the thicker the wedge the greater the deflection, because, regarded as a wedge, the glass plate with parallel sides was the thinnest possible—and then the deflection was zero. And here, of course, by thickness we mean the angle between the two faces and not the thickness in inches, which for a prism would be a bit vague.

Now suppose we look at our magnifying glass. It has two rounded surfaces—portions of spheres as a matter of fact. What happens when we hold it in front of our old-fashioned lamp bulb? Well, consider the light which is coming from one single point on the filament—a part of it is coming straight at the center of the lens—if it gets a slight deflection as it passes into the glass, it gets a nearly equal one in the opposite direction as it passes out because if we were to hold stiff cards against the lens, one where the light enters and the other where it leaves, the two cards would be nearly parallel—so far as this particular bit of light knows, it has passed through a glass plate and it isn't deflected. But what about other beams or pencils of light from the same point on the filament? We look at one which strikes near the edge of the lens. If we do the same trick with the cards we find that they make quite a considerable angle with one another—so this beam of light

is deflected quite a lot—away from the edge and so toward the beam that went straight through. Now perhaps you see how it is—the more the beam misses going through the center of the lens, the more it is deflected towards the center—all these beams which passed through the different parts of the lens have a chance of coming together again somewhere beyond. Well, that's just what they do; they all come together at a point and this point lies on the beam which passed through the center of the lens and was not deflected, because this is one of the whole collection of beams which comes together. So, you see, all the light which started from a single point on the filament and passed through the lens has come together again at a single point beyond the lens. And this goes from all other points on the filament which send light to the lens—each of them has its own light brought together in a point or focus and all these foci taken together constitute the image of the filament which appears on the wall and so impresses the children with our cleverness.

Now I am really supposed not to be talking about light at all but about electrons. The quickest way of getting over where I belong is to say that the filament of the lamp sends out not only light but also electrons, which is illuminating if you happen to know what electrons are, but not otherwise. For the benefit of those who know what light is but are a bit rusty on electrons, I will say that they are quite small electrically charged particles which are more numerous perhaps than anything else in the universe. They flow through the lamp filament and keep it hot, and some of them come popping out through the surface. They do not get far, however, not those which come out of the filament of an incandescent lamp. They are caught in the electric field inside the bulb, whisked about over curved paths and sent back into the filament. They do not affect the lamp one way or the other. It would look just the same if they did not come out at all. In a radio tube things are different. It is the electrons that count and not the light. It is arranged so that the electrons, instead of going back into the filament, flow from the filament across to a metal plate and then out of the tube through a wire. Just how this makes it possible for you to hear what I am saying is rather a long story with which we are not now concerned. The point is that hot filaments send out two things, light and electrons. In the incandescent lamp we make use of the light; in the radio tube we make use of the electrons.

And now we ask this question. We have seen how it is that an image of the filament can be formed with light—can the same thing be done with electrons? Can all the electrons which come from a single point on the filament—or a lot of them be brought together at another point, and can this be done for all points so that an image of the filament is formed in electrons as in light?

Well, it does not look easy. In the first place, the electrons do not come out through the glass bulb, so if we want to form such an image we will have to form it inside the bulb. Even so, how are we going to see it, suppose we do succeed in forming it? We can not be inside the bulb ourselves and even if we could electrons can not be seen the way we see light with our eyes. When we form an image of the lamp filament on the wall, the light is scattered by the paper—some of it enters our eyes and so we see it. Well, this, as it happens, is the least of our difficulties. There are a lot of different substances—zinc sulfide, for one—which when electrons strike them, shine out. They shine out only where they are struck, so that if we had our electron image formed we could see it by having it on one of these fluorescent screens. It is a special kind of wall paper, so to speak, suitable for seeing

electron images. Well, it is something to know we could see it if we had it. All we have to do now is to figure out how to produce it.

One way of not doing is to use a magnifying glass, because, of course, electrons do not go through glass. They do not go through anything really—not to go in one side and come out the other—not the ones we can work with conveniently in a bulb.

But there are more ways than one of killing a cat. Why send the electrons through a solid material at all, especially as it can not be done. The reason for sending the light through the lens was to deflect it. The deflection was the important thing—not the sending through. Even with light the sending through is not essential; the direction of a light beam can be changed by reflection and light images can be formed by properly shaped mirrors. But here again the method can not be used with electrons; there is no such thing as an electron mirror.

We just forget about glass lenses and curved mirrors and think of the ways in which beams of electrons can be deflected. There is no difficulty in deflecting electrons. It is more difficult not to deflect them. They are deflected in magnetic fields and in electric fields. Let us take an ordinary radio tube and make a small hole in one of the plates that enclose the filament. If we apply a positive potential to the plate—that is, if we connect the positive end of a battery of dry cells to the plates and the negative to the filament—then the electrons which come out of the hot filament will be drawn across to the plates. They move like falling bodies; their speed is continually increasing from the time they leave the filament until they reach the plate. Some of them will pass through the small hole and continue on as a beam. While we are about it, we will suppose that we have joined a long tube to the radio bulb opposite the small hole in the plate and that we have set up one of those fluorescent screens at the end of it which shines out where electrons strike it. The beam strikes the screen and a spot shines out. If we bring up a magnet to the side of the long tube, the spot moves across the screen—the beam is deflected by the field of the magnet. If we try this with a beam of light, nothing happens.

We now place in the tube two metal plates so that the beam passes between them and connect the two plates to the ends of another battery of dry cells. When the connection is made the spot of light on the screen jumps to a new position. The beam has been deflected toward one of the plates and away from the other. We reverse the connections and the beam is deflected in the opposite direction. A beam of electrons is deflected by an electric field. Try this on a beam of light and again nothing happens.

Well, you see we have two ways of altering the direction of a beam of light—by reflection and by refraction—and two ways of altering the direction of a beam of electrons by a magnetic field and by an electric field. In the optics of light the problem is to so shape our reflectors and our refractors as to cause the light radiating from a luminous point—or a part of it—to come together again at some other point—to be brought to a focus. The answer to the problem is curved mirrors and glass lenses.

In the optics of electrons the problem is to so shape our magnetic fields and electric fields that the electrons emitted from a point will likewise be brought to a point focus. We have been working on this problem of shaping fields into lenses at the Bell Telephone Laboratories now for several years; Mr. Zworykin at the R. C. A. Laboratory in Camden has been working on it; a lot of people in Germany have been working on it, and we have all had quite a lot of success. We all produce images of hot surfaces in the electrons which they emit and we all produce electron images of wire gauzes and of holes punched in metal plates.

This is like producing an image of a lantern slide on a screen—only these images are produced in electrons instead of light. How is it done? Well, in the first place, the electrons must always be speeded up by an electric field as happens when they pass from filament to plate in a radio tube. Then those which started from a given point on the emitting surface must be deflected by different amounts according to the different paths they may be on so that their paths will all cross at a point on the fluorescent screen. One way of accomplishing this is to pass them through a small circular coil of wire carrying an electric current—there is a magnetic field in and about such a coil and it happens that its shape—its distribution—is such that it behaves with respect to electrons as a glass lens does with respect to light. It brings the electrons which pass through it to a focus. There is the same sort of correspondence between emitting points and foci as in the light optical case—so that the assemblage of foci forms an image of the emitting surface.

Another way of doing the same thing is to pass the electrons through a hole in an electrically charged plate—the field about such a hole has just the right shape or distribution to serve as a lens. Magnetic lenses are always positive; that is, they are always like convex glass lenses—they always try to bring electrons toward a focus somewhere beyond. Electric lenses are different—they are positive or negative, depending on the potential or voltage of the plate containing the hole relative to other parts of the system. The hole we imagined cut in the plate of the radio tube would be a negative lens; it would be like a concave glass lens—it would fan out slightly the electrons passing through it so that they would be proceeding from a focus back of the plate, not toward one in front of it. To produce an image on the screen we would have to use at least one more plate containing a hole. By passing the electrons through holes in two plates and having the plates at the right voltages the trick can be turned—an image can be formed on the screen.

But why bother? Why go to all the trouble of building up these systems in vacuums to produce images in electrons when perfectly good light images can be produced so much more easily? Well, there are a number of reasons. I will mention one of them only. The highest magnifying power worked with microscopes is about 3,500. This is not because microscopes of higher magnifying power can not be made. We could just put one microscope above another if we liked and have a magnifying power of 3,500 times 3,500. Why isn't this done? Well, it is a matter of resolution. The light from a point in the object does not appear as a point in the field of the microscope—it appears as a spot, a very small spot, but nevertheless a spot. So that two points in the object, if they are very close together, will produce two spots which overlap and so appear to the observer as one spot. The points in the object are not resolved, as we say, in the field of the microscope. And if we added a second microscope to the first, they would not be any better resolved in the field of the second—they would not be as well resolved in fact. Now the size of these spots, and so the resolving power of the microscope, are determined in part by the wave-length of the light—the greater the wave-length the larger the spot and the lower the resolving power. This is why some microscopes are made to operate with ultra-violet light—the wave-length is less and the resolving power higher. Now electrons, strangely enough, have wave-lengths like light—only they are very much less—of the order of one one-thousandth that of ultra-violet light. The situation is then that the ultimate limit of resolving power for an electron microscope is about a thousand times higher than for a light microscope. We are a long way from attaining this limit, but we are on our way.

THE LIVING CELL

By Dr. ROBERT CHAMBERS

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THE invention of the compound microscope in the seventeenth century led to the discovery that all living organisms, both plant and animal, from the largest to the smallest, are composed of minute bodies called cells. These cells are such highly organized and self-sufficient units that millions of organisms consist of just one cell, for instance, all bacteria.

There are two good reasons why we are interested in living cells; one is our natural curiosity regarding these minute structures which embody the mystery of life and, second, the realization that investigations concerning cells bring us to the very root of the problem as to how the organs of our bodies function. It is the knowledge of this upon which medical science depends.

Cells have been a favorite object of study for a long time, but only within comparatively recent years has it been possible to subject them to experimental analysis. One of the difficulties is their small size. If we were to take average sized cells and spread them over an area of 1 square inch we would need 400 to 500 million cells to cover the space. Another difficulty is getting at them without the risk of injuring them. The great majority of the cells are bound together firmly to constitute the organs of our bodies. Others, which are among the smallest of cells, lie in the blood and body fluids where they are free to move about.

One of the most promising methods devised within the last twenty years for examining living cells depends upon the discovery that tiny fragments cut from living tissues will survive in a drop of blood outside the body. The cells in the fragment spread out and continue to grow and multiply under conditions where they can be clearly observed through a microscope. Another useful method has been made possible by the invention of a mechanical contrivance which enables the experimenter to use exceedingly fine glass needles for manipulating individual cells in the highly magnified field of the microscope. In short, the past fifteen years have been marked by developments which enable us to work on the problem in a much more direct manner than had been possible before.

At present what do we know about the cell? We know a great deal of what it is capable of doing, but we are woefully ignorant of how it does it. This is because our knowledge of its constitution is still in its veriest infancy, and even our speculations regarding it are far from satisfactory.

It has been shown experimentally that the cell is a fluid body, marked off from its surroundings by a well-defined boundary or membrane. If our bodies were composed of nothing more than these cells we would be only flabby lumps of jelly. However, many of the cells deposit about them solid materials which form our bony skeleton and, in plants, the woody parts.

The fluid of the cell is in constant motion, although some parts are denser than others. Such differences in density suggest some kind of an internal organization. Within this fluid we find an oval or round body which is invariably present. It is called the nucleus of the cell.

The membrane which encloses the fluid cell has such surprising properties that some investigators regard it as being that part of the cell which is chiefly responsible for the processes which make life possible. It has the faculty of selecting certain substances to pass into the cell and it rejects others. This membrane is not a permanent fix-

ture but is constantly being broken down and as constantly being repaired. The properties of the membrane are so intriguing that we have to-day a school of so-called membrane physiologists who are experimenting in the laboratory with all sorts of membranes and films in the search of a material which will, in some measure, duplicate the properties of the living cell membrane. On the basis of this idea one of the prime functions of the materials within the cell seems to be to keep its membrane intact and in the proper working order.

The condition of this membrane may be illustrated by a crude analogy of a country at war with a thin line of defending troops surrounding it. As long as the line is intact all is well. The personnel of the line is ever changing through individual replacements. Wherever the line breaks reinforcements are rushed from the interior to fill the gap. From the air the interior of the country appears to be in turmoil with troops and lorries traveling in all directions. Evidence of orderly arrangement is most apparent along the thin extended line surrounding the whole. Such is the cell membrane. The life of the cell and indeed life in general is a continual adjustment of internal to external conditions. This means continual work with a constant expendiutre of energy, which is obtained by the cell through nourishment.

How long do cells live? To answer this question we must first realize that all cells can divide into two young daughter cells. This process of cell division is periodic and, in the interval between successive divisions, the two daughter cells grow to the size of the mother cell. In young organisms the cells multiply rapidly from hour to hour. As the organism ages the rate slows down until, when maturity is reached, many cells may carry on for years without appreciable change. However, if an injury should occur the cells can again divide and grow until they have replaced the mutilated tissue. This indicates that the potentialities for continued growth are still present, even in old organisms. Under normal conditions these growth potentialities are held in check. Otherwise, there would be nothing to stop the cells from converting us into continually growing and monstrous giants!

The latent ability of cells to grow without control flares into activity in the dread disease of civilization, cancer. The cells which are affected by this disease lose their subordination to the general economy of the body. They continue to multiply and grow to form the insidious tumors which destroy the body in which they grow.

Cancer differs from the usual human afflictions in being a peculiar state of the living cell. In other diseases our resistance is lowered because our cells weaken and we succumb because our cells die. In cancer, on the other hand, the involved cells are healthy and vigorous, but they are so altered as to have lost their original functions. They persist and grow as living cells but with relationships which are chaotic and vicious.

It is an interesting fact that several of the activities characteristic of the living cell have been successfully imitated with lifeless chemical compounds. This is nothing new. For many years investigators have prepared mixtures of various substances which are amazingly lifelike. They simulate cells in the way they move, subdivide and even grow in size. Some of these mixtures even take up oxygen and give off carbon dioxide, thus breathing superficially in the same way that cells do.

One of the properties of all living cells which is especially evident in cancer cells and which still baffles imitation is the periodic rejuvenation and development of fresh vigor each time the cells divide. The pronounced manifestation of this property in cancer cells suggests that the essential problem of cancer and of cellular physiology are one and the same.

PSYCHOLOGY AND REEMPLOYMENT

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"WHAT am I going to do about a job?" is a question which gives more concern to each of us—at one or another time of our lives—than any other that is ever asked. At the moment it overshadows all others in the minds of 7 or 8 millions of people who are out of employment. Perhaps to a greater degree than most of us suspect this query is bothering the young people in our high schools and universities, to whom the future presents itself in the form of a large question mark with respect to the important problem of how they are going to earn their living.

The depression has given additional emphasis to this question of the job. It must be remembered, however, that it is present even during so-called prosperous or rich years. It always presents a problem to young people who are for the first time faced with a choice of a career. It is also becoming a question of increasing importance to men in their prime who are thrown out of jobs which they have held for many years because of changes in methods of work or because of variations in demand that make their particular jobs unnecessary. To such men particularly the fear of continued unemployment is an ever-present specter. And, it is important to note, few experiences can be more disturbing to mental health than the haunting fear of losing a job under which so many employed workers are laboring to-day, or the discouragement, the hopelessness, the sense of futility awakened by the inability of the individual to sell his services in the labor market.

A recent study by Hall,[1] of the Personnel Research Federation, gives evidence of this relationship between unemployment and morale. A group of unemployed and a group of employed engineers were compared with regard to occupational morale, attitudes toward employers as a class, etc. Seventy-five per cent. of the unemployed men had poorer morale than the average employed men, and 68 per cent. were more antagonistic toward employers as a class.

The morale of destitute men who had been given "work relief" or "made work" was found to be definitely better than the morale of men who, although similarly destitute, had not received such help. The morale of employed men who anticipated losing their jobs almost any time was as low as that of unemployed men who were in no particular need. In general, the results support the opinion that the grave consequences of unemployment reach beyond material discomfort, beyond the disintegration of skill and health, to undermine a man's attitudes toward his fellows and toward political and social institutions.

According to one estimate, 10,000,000 men who have been employed on white-collar jobs will be forced, during the next 10 years, into manual jobs.[2] Another 15,000,000 manual workers will find it necessary to transfer to jobs requiring skills other than those to which they have been trained. Men thrown out of work by technological changes and for other reasons over which they have no control must be quickly fitted into new forms of work or into already existing occupations where jobs are made available by a decrease in the number of work-hours or through other measures.

[1] O. M. Hall, "Attitudes of Unemployed and Employed Engineers," *Pers. Jour.*, 12: 222–28, 1933.

[2] W. B. Pitkin, "More Power to You," p. 13, Simon and Schuster, New York, 1933.

In the case of these men there is no time to be wasted in trying out one or another job until by chance each finds that for which he is adapted. The rapid adjustment and effective use of this man-power require an exact analysis, by appropriate psychological techniques, of qualifications for work. Only in this way can there be sound and rapid reeducation and placement of each in accordance with the new needs of industry and with the specific qualifications of each worker involved. This means also that traditional notions of vocational fitness must give way to the use of psychological methods in measuring human capacities, temperamental traits, interests and skills that underlie job success. The findings and work of the Stabilization Research Institute of the University of Minnesota, of the Adult Vocational Guidance Clinic conducted by the speaker and of the Vocational Adjustment Service of New York point to the possibilities in this direction. The proposal for testing centers in public employment offices may well mark the end, in the United States, of the attitude that natural selection will ultimately place each individual in his proper economic niche, and the opening of an era of classification and placement on the basis of an exact knowledge of each individual's fitness for work.[3]

The analysis of individual ability, emotional characteristics and interests is only the first step in a scientific program for putting displaced labor into new fields of employment. This must be supplemented by psychologically sound training programs for teaching men the new jobs for which they are qualified.

Industry and vocational schools can very well cooperate to their mutual advantage in the formulation and administration of such programs. Industry, for example, can facilitate transfer within the organization by training its experienced workers—particularly the older ones—in the principles and practises of the jobs to which each can be most easily transferred in case of replacement of his job by machines, of changes in company practises or of temporary economic depression.

The application of this policy may mean, for example, that meter readers in an electric and gas utility will be trained not only in the approved practises of meter reading, but will also receive detailed instruction in the work of the bill collector, the job to which meter reading is related most closely on the organization chart. Employees in traditional coke gas-making plants will become acquainted with the reformed oil process, in preparation for the day when a shift in operating practise may be found necessary, etc. That this is a practicable program has been demonstrated in the work of a number of progressive organizations, such as the Philadelphia Electric Company, which have formulated such training plans as an aid in transferring to available jobs employees who would otherwise be dropped from the payroll.[4]

The vocational school also has a responsibility in this connection. Many of them are still training men for trades which have either disappeared or been completely transformed in the last 10 years. It is apparent that the entire program of vocational education in the schools is in need of reorganization, so that training may cover the exact processes now employed and trades or jobs in the process of development. There is also reason to believe that the vocational schools can make a most important contribution in increasing the general skill and dexterity of those whom they train.

Wherever possible, it is necessary for vocational schools to conduct training so

[3] D. G. Paterson, in J. G. Darley, D. G. Paterson, I. E. Peterson, "Occupational Testing and the Public Employment Office," p. 4, *Employment Stabilization Research Institute Bulletin No. 19*, University of Minnesota, 1933.

[4] M. S. Viteles, "Adjustment in Industry through Training," *Pers. Jour.*, 11: 295–306, 1933.

as to create in the individual a set of fundamental skills that can be used in many jobs, thereby providing for quick adaptation to rapidly changing forms of work. How to develop such adaptability is a psychological problem. The cooperation of the psychologist is needed in formulating methods which will be adequate from the view-point of underlying psycho-physiological processes as well as from the view-point of the working situation. In formulating these techniques certain fundamental questions will have to be answered—such questions as:

Is there a small number of basic capacities underlying skill which can be developed in order to create in the individual a set of fundamental skills that can be used in many jobs, thereby providing for rapid adaptation to rapidly changing forms of work?

Is there a transfer of skill? How can it be used in promoting a better adaptation to work?

Is it possible to make, early in the life of the individual, an analysis of specific abilities and other traits as a basis of outlining a training program best adapted to his needs, to avoid placement in an occupation in which he can attain only the proficiency level of the "marginal worker"?

These and similar problems are being investigated in the psychological laboratory to-day. The answer given to them will to some extent determine the measures to be taken by society in adjusting men to the rapidly changing needs of industry or perhaps, in certain instances, of controlling these changes better to meet the fundamental needs of men.

As Thorndike, of Columbia University, has pointed out, "a steady, industrious, reliable worker has qualities of body and mind and morale which are too important to be wasted because some industrial change has destroyed the value of the special work which he has hitherto performed."[5] Provision for his transfer to suitable and available work must be made. This calls for an extended public program of individual analysis, retraining and replacement, as a focal point for individuals who need guideposts to economic stability and occupational adjustment. The past few years have shown the bewildering lack of such guideposts. Individuals need to be directed to economic stability through occupational analysis and individual planning. The fulfilment of this need calls for the development of a new type of social institution—the Adult Occupational Adjustment and Employment Service. The progress that has already been made in the establishment of such centers and in the development of sound psychological techniques for their use represents a distinct advance in the direction of a healthier occupational system.[6]

[5] E. L. Thorndike, "Adult Learning," p. 180, Macmillan Company, New York, 1928.

[6] J. G. Darley, D. G. Paterson and I. E. Peterson, *op. cit.*, p. 28.

MIRROR MAKING BY THE EVAPORATION PROCESS

By ROBLEY C. WILLIAMS
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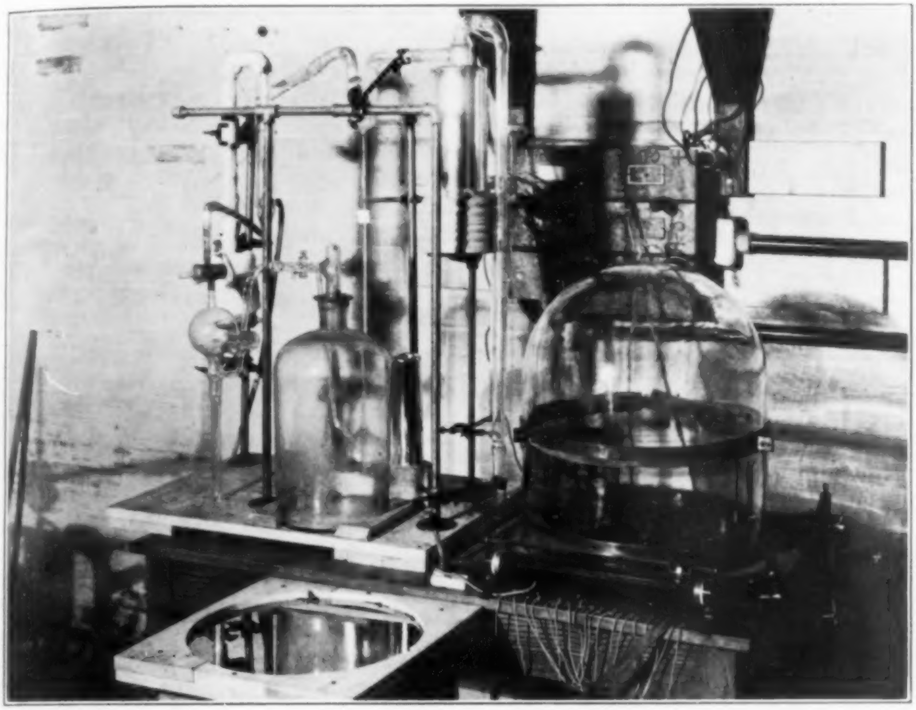
RECENTLY a laboratory technique has been developed for coating glass surfaces with metals, which bids fair to displace the former processes by which silver was chemically precipitated upon glass. The deposition of the metal is done by evaporating it in a vacuum chamber and condensing the metal vapors upon the glass to be coated, which is nearby in the chamber. The process accordingly has come to be called the "evaporation process." Mirrors made in this way are generally front-surface mirrors and are of great value to the scientist for the properties of hardness, untarnishability and reflectivity.

The uses and possibilities of this process are manifold. Mirrors for use in work where excellence and uniformity of the metal surface is demanded, and where unusual reflecting properties are advantageous, are best made by evaporation. Glass diffraction gratings, with thirty thousand rulings to the inch, have been coated with metal in this fashion, and so thin is the film that the rulings have not been noticeably filled in, while the brilliance of the spectrum obtained from the grating has been increased many-fold. Quartz fibers for electrometer suspensions are made conducting by evaporating upon them a layer of gold. This was formerly done more slowly by sputtering. Films can be made of varying thicknesses and yet thin enough to transmit some light, and hence can be used as light filters. Cellophane has been coated with aluminum and then used as a window on an x-ray tube, the aluminum serving to filter out the soft x-rays.

To astronomers in particular the process is attractive. Until now all glass astronomical mirrors have been covered by chemically deposited silver, which limits the range of wave-lengths that can be investigated in stellar spectra. Of course, the opacity of the earth's atmosphere prevents photographing wave-lengths shorter than 3000 Angstrom units, but silver becomes relatively useless at 3500 Angstrom units. Consequently this ultra-violet region from 3000 to 3500 Angstrom units has been investigated for only the brightest stars. The advent of evaporated aluminum mirrors allows the astronomer to examine stellar spectra of wave-length as short as the atmosphere transmits, and furnishes him further with a mirror surface which will not tarnish and which is considerably harder than the silver-on-glass surfaces.

The process is not new, and several have contributed to its present state of development. Its forerunner was the cathodic "sputtering" technique by which a metal is bombarded in a partial vacuum by high-velocity ions of a suitable gas, and pieces of the metal are knocked off. The glass to be coated is in the same chamber, and the metallic particles which have been "sputtered" off adhere to the glass. The deposition goes on very slowly and is limited practically to small surfaces. Metals which form oxide coats, like aluminum, can not be readily deposited by cathodic sputtering.

As long ago as 1894 Edison realized the possibility of thermally evaporating metals in a high vacuum, and he obtained a patent upon this idea in that year. He experimented with three methods of deposition: the use of an arc the electrodes of which were of the metal to be deposited; the heating of a wire of the desired metal almost to the melting point with consequent slow sublimation; the use of carbon vessels as heating ele-



THE FIRST MULTIPLE-FILAMENT APPARATUS USED AT CORNELL TO COAT LARGE MIRRORS BY EVAPORATION

ments upon which the metal was to be placed. Evidently the technique was none too successful, for little was done with it at that time.

Subsequent to Edison's patent, various patents were granted upon variations of the principal idea, but no significant advance was made until about 1929. Some years prior to this a valuable spectroscopic instrument had been perfected, the Fabry-Perot interferometer, which has as its principal parts two plane, half-silvered, glass plates. Although opaque silvering is done very successfully by the chemical process, it is almost impossible to obtain satisfactory half-transparent films. Consequently, experimentalists at the Physikalische Technische Reichsanstalt in Berlin investigated the evaporation technique for use with these interferometer mirrors. They were aided by the developments that had been made in producing tungsten wire of all sizes and were able to use this metal as the heating element instead of the carbon tried by Edison. They were very successful in employing the method for half-silvering and obtained films of silver that were uniform, unpitted and capable of reflecting 95 per cent. of the incident light. Furthermore, they produced films of aluminum alloys that gave excellent reflectivity in the ultra-violet region of the spectrum.

About a year later work on the process was begun in this country at the California Institute of Technology and at Cornell University. These institutions developed vacuum chambers which allowed experimentation with many shapes and sizes of glass and with the use of a plurality of heating elements. In the summer of 1931 the Cornell investigators began to consider the possibility of using the process for large astronomical mirrors. They hoped to find a metallic surface to take the place

of chemically deposited silver which tarnishes, reflects very poorly in the ultra-violet and is quite soft. The following summer they coated the Lowell Observatory 15-inch mirror with chromium, and used this in an attempt to photograph the ultra-violet spectrum of the corona during the 1932 total solar eclipse. Chromium was chosen for its extreme permanence and its excellent relative ultra-violet reflectivity. This mirror was the first astronomical mirror to be coated by the evaporation process. The work has been extended so that at the present time there are numerous institutions working on the problem. The 36-inch astronomical mirror of the Lick Observatory, which has recently been covered with aluminum in a 40-inch vacuum chamber at the California Institute of Technology, is the largest mirror yet coated.

As previously stated, the essential parts of the apparatus are a vacuum pumping system, a vacuum-chamber to contain the glass surface, and the heating elements, and supports for the electrically-heated tungsten wires upon which is placed the metal to be evaporated. For the first, a large oil fore-pump and a mercury or oil-diffusion pump is used. Since a pressure of about one ten-millionth of atmospheric pressure is needed, the pumps must be fast and efficient. The vacuum-chamber is generally a glass or metal dome waxed down to a metal bed-plate with low vapor-pressure wax. In the bed-plate are mounted insulated lead-wires which connect to the tungsten wires to be heated. The tungsten wire is generally wound into a straight helix or a conical helix, and the metal to be evaporated placed within. The object to be coated is placed in the chamber and is often suspended inverted over the tungsten filaments at a distance of a few inches. The glass surface must be cleaned with utmost care, and a method of cleaning by electron bombardment has recently been developed at the California Institute. After the glass and filaments have been placed in position and the desired vacuum obtained, the actual evaporation of the metal takes only a few minutes. The mirrors thus made require no further treatment and, in fact, an attempt at polishing may result in marring them. The films are only about one one-hundred-thousandth of an inch thick, and hence fit the contour of the glass surface exactly.

The properties of these metallic films for use as mirrors vary widely. At the present writing about twenty-five different elements have been evaporated. Included are common elements like silver, gold, copper and aluminum, and rarer ones like germanium, selenium, palladium and beryllium. Those elements with extremely high melting points or which attack the tungsten filament upon being heated are extremely hard to evaporate. The former problem is being solved at the Massachusetts Institute of Technology, by bombardment of the metal to be evaporated by high-velocity electrons. The ideal metallic mirror coating, of course, is one that is permanent and hard, and which possesses high reflectivity throughout the spectrum. No element yet evaporated fully satisfies all these requirements. Chromium is so hard and resistant that it can be removed from glass only with abrasives, yet its reflectivity is below that of some other metals. Although some other metals have a higher reflectivity than aluminum in certain regions of the spectrum, aluminum has an average reflectivity for the entire spectrum range higher than that of any other metal. Furthermore, due to the formation of a thin, transparent oxide coating over the metal surface, aluminum films do not tarnish, but they are too soft to be ideal. Aluminum is the best all-around mirror surface yet developed, however. Alloys have been worked with, and there are possibilities that eventually the ideal mirror will be produced from them.

THE PROGRESS OF SCIENCE

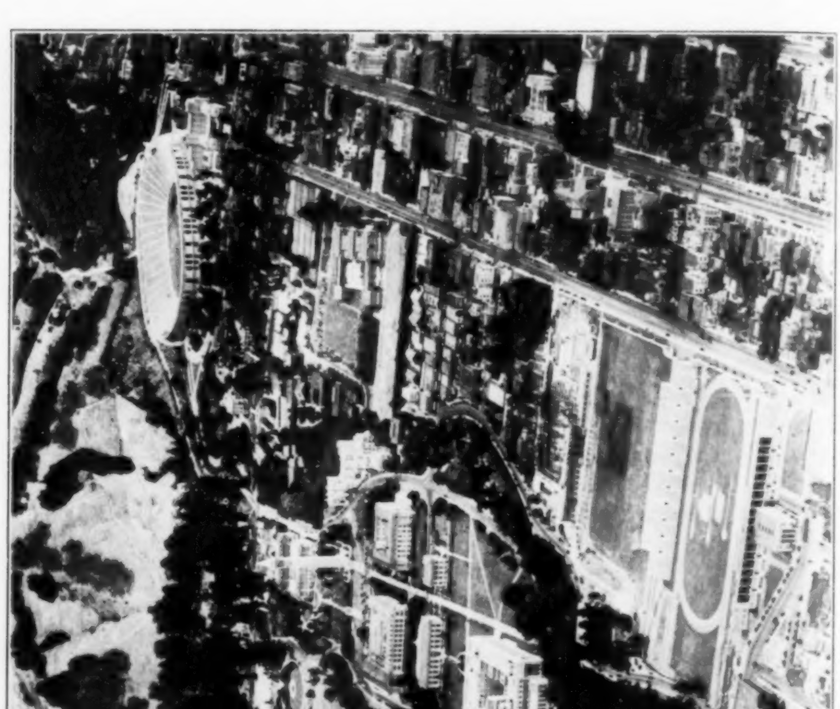
THE BERKELEY MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE ninety-fourth meeting of the association was held at Berkeley in June under the joint auspices of the University of California and the Pacific Division of the association. It attracted a large attendance; 1,164 persons registered for the meeting and several hundred others who failed to do so participated in some of its numerous sessions. Nine tenths of the registration came from the region included in the Pacific Division, the remaining one tenth from more distant localities, a number from foreign countries. This meeting was the second national meeting in the San Francisco Bay Region, a previous summer meeting having been held in 1915 during the Panama-Pacific Exposition.

Details as to arrangements for the meeting were left largely in the hands of the local committee. Besides its customary duties it was called upon to assemble the program material and to prepare it for printing and to handle publicity. By an arrangement with Mr. Austin H. Clark, the preparation of news releases and other details in connection with publicity were delegated to Mr. George A. Pettitt, of the University News Service, who organized and conducted a press bureau where abstracts and manuscripts, as well as the necessary physical facilities, were available to news correspondents. This news service was widely used and instrumental in securing extensive publicity for the meeting not only in the local but also in the national press. Authority for preparing programs was largely delegated to secretaries *pro tem*, appointed for the meeting by the permanent secretary on nomination of the local committee, and most of the associated societies delegated the responsibility for assembling their programs to local representatives. This innovation proved very successful since it promoted a close contact between the local committee and the various persons responsible for the preparation of programs. It also facilitated assignment of rooms and provision of physical facilities, since the local representatives were familiar with conditions at Berkeley. This arrangement was no doubt largely responsible for the smoothness with which the meeting was carried out.

The meeting occupied an entire week, Monday to Saturday, inclusive, from June 18 to 23, 1934. The first plan was to devote morning periods to scientific sessions; afternoons to informal conferences, excursions, field trips, social affairs, etc., and evenings to general sessions featuring speakers of national prominence. When the program material was received, however, it so far exceeded expectations that most of the sections and societies were forced to schedule additional sessions, with the result that afternoon periods were also largely given over to scientific sessions.

Five evening sessions were arranged by the permanent secretary, Dr. Henry B. Ward, and they were well attended, not only by participants in the meeting but also by the general public. On successive evenings Dr. Joel H. Hildebrand delivered the retiring address of the president of the Pacific Division on "The Liquid State"; Dr. L. Dudley Stamp delivered the third Hector Maiben lecture on "Planning the Land for the Future"; Dr. J. C. Merriam spoke on "Responsibility of Science with Relation to Government Problems"; Dr. E. B. Wilson discussed the topic, "Are There



AIRPLANE VIEW OF THE BERKELEY CAMPUS OF THE UNIVERSITY OF CALIFORNIA

Periods in American Business Activity?"; and Dr. Karl T. Compton delivered an address on "Science and Prosperity." The assignment of the Hector Maiben lecture to the summer meeting was particularly appreciated; and it is hoped will lead to the development of other special features for forthcoming summer meetings.

At business sessions of the Pacific Division, Dr. Bailey Willis, emeritus professor of geology in Stanford University, was elected president of the division, succeeding Dr. Joel H. Hildebrand, and Dr. W. V. Houston, professor of physics in the California Institute of Technology, was elected to the executive committee in succession to Dr. S. J. Barnett, professor of physics in the University of California at Los Angeles.

Besides the general sessions a number of features arranged by sections and societies were of more than special interest. These included addresses by E. A. Sperry on "The Automatic Pilot"; by Göte Turesson on "Ecotype Constitution and Geographic Distribution"; by Professor H. C. Thompson on "Relation of Temperatures and Length of Day to Reproduction in Plants"; and by Robley D. Evans on "Radioactivity and the Age of Meteorites." Dr. C. A. Kofoid presented the new edition of the Canti film with slides, and original films on "American Mammalian Trypanosomiasis" by Dr. C. A. Kofoid and on "Development of the Amphibian Egg" by Professor J. A. Long were shown at another public session. On Friday, through the courtesy of the Commonwealth Club of California, national officers, speakers and presiding officers at the general sessions of the association were present as guests of the club at its regular luncheon meeting in the Palace Hotel in San Francisco, at which Dr. R. A. Millikan spoke on "Science and National Welfare."

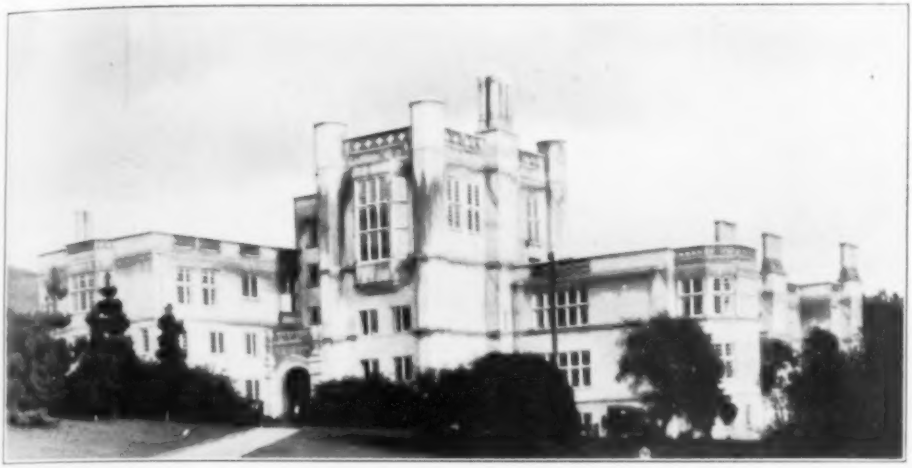
Social features of general interest included a reception held on Monday evening, following the opening general session, at which music, dancing and refreshments were enjoyed by those in attendance; and general teas on Tuesday afternoon at the Women's Faculty Club and on Wednesday afternoon at the International House, at which a program of Japanese music, dancing and flower arrangement was featured and Japanese ladies in native costume served refreshments. Besides the general social events, numerous luncheons and dinners were arranged by special groups. Some of these dinners were followed by programs of various kinds; as, for example, the biologists' dinner, at which Dr. A. F. Blakeslee gave a demonstration of differences in perception as to taste and smell and spoke briefly on the inheritance of such variations; the engineers' dinner, at which the Daniel Guggenheim Medal was presented to William Edward Boeing, and Chester Harvey Rowell spoke on "Regimenting the Professions, Engineers Included"; the physicists' dinner, at which Professor R. W. Wood spoke on "The Physicist as a Detective"; and the psychologists' dinner, at which Dr. E. R. Guthrie delivered the presidential address on "Skill and Associative Learning." The numerous luncheons, dinners and other social affairs unquestionably contributed largely to the informal and friendly atmosphere which was characteristic of the meeting.

Special affairs arranged for visiting ladies included a garden tour, a tour to Mills College, a personally conducted trip to Chinatown and a tea at the College Women's Clubs. Besides these affairs visiting ladies participated in the general social events and in the luncheons and dinners arranged by special groups. Excursions were also arranged to Davis to visit the branch of the College of Agriculture; to Mt. Hamilton to inspect the Lick Observatory; to Stanford University, where a special program was arranged and a booklet descriptive of the university was distributed; and to

PORTRAIT OF BAILEY WILLIS
EMERITUS PROFESSOR OF GEOLOGY IN STANFORD UNIVERSITY, NEWLY ELECTED PRESIDENT OF THE PACIFIC DIVISION, A. A. A. S.

the California Academy of Sciences, which served a complimentary buffet luncheon to about 175 persons in their Simson African Hall. Visitors were given an opportunity to inspect the departments and exhibits of the academy and in the afternoon they were given a free automobile bus tour of San Francisco through the courtesy of the San Francisco Chamber of Commerce.

On Tuesday afternoon many of the university departments held open house, at which an attempt was made by means of informal exhibits and demonstrations to acquaint visitors with research activities of the university. A special exhibit of books of epochal significance in the history of science, selected under the supervision of Professors H. M. Evans and J. W. Thompson, attracted a great deal of attention. A booklet containing annotations on the items included in the exhibit was prepared and printed for the meeting. The exhibit included an



STEPHENS UNION BUILDING

HEADQUARTERS OF THE ASSOCIATION FOR THE BERKELEY MEETING. THE REGISTRATION OFFICE AND QUARTERS FOR THE NATIONAL OFFICERS WERE LOCATED HERE, ALSO SPACIOUS LOUNGING ROOMS WHICH SERVED AS A CENTRAL GATHERING PLACE DURING THE MEETING.

extensive collection of portraits of scientific worthies, mostly in the form of engraving, from the private collection of Professor H. M. Evans and portions of the Hearst Medical Papyrus. The National Park Service, through the courtesy of Ansel F. Hall, placed a large collection of relief models of national parks on exhibit. Besides the specially prepared exhibits, a number of the university collections were thrown open to inspection throughout the week.

Space forbids any detailed account of the special programs of sections and associated societies. Of the fifteen active sections of the association, fourteen were represented by extensive programs. No attempt was made to arrange a program in geology and geography, owing to the fact that associated societies in this field

LIFE SCIENCES BUILDING

IN WHICH MOST OF THE SESSIONS IN THE BIOLOGICAL SCIENCES AND IN RELATED FIELDS WERE HELD.

PORTRAIT OF JOEL H. HILDEBRAND
PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF CALIFORNIA, RETIRING PRESIDENT OF THE PACIFIC DIVISION, A. A. A. S.

on the Pacific Coast had held a joint meeting in Berkeley in April, which was well attended and brought forth a very extensive program. Nevertheless, this field was represented by a joint luncheon conference of the Committee on Oceanography of the Pacific and the Western Society of Naturalists. Eight hundred and fifty papers are listed in the special programs and 36 associated societies and other organizations cooperated with the sections in the meeting. Copies of the complete program may be obtained from the permanent secretary.

Several sections which frequently are not well represented at association meetings presented extensive programs at this meeting. The Social and Economic Sciences, in cooperation with the Econometric Society, the American Statisti-

cal Association and the Western Farm Economic Association, presented a program consisting of no less than twelve sessions and in addition joined with Agriculture in a three-day program on "Land-Use Planning." Agriculture was also represented by a specially arranged symposium on "Weed Control," in which fundamental features of the problem were emphasized, and by sessions of the Western Society of Soil Science, which devoted one day to a symposium on "Phosphate," and of the American Society of Agronomy (Western Branch). The Historical and Philological Sciences and the Medical Sciences were represented by a unique symposium on the Hearst Medical Papyrus, portions of which were included in the exhibit of old books. The program of the Medical Sciences opened with a memorial service in honor of Dr. William H. Welch, at which J. McKeen Cattell presided and Ray Lyman Wilbur spoke on the life and work of Dr. Welch. The remaining portion of the program in the Medical Sciences was devoted to endocrinology, nutrition, hygiene and epidemiology and parasitology. Sessions were also held by the Society for Experimental Biology and Medicine (Pacific Coast Branch) and the California State Veterinary Medical Association. Engineering was represented by programs of the Aeronautic and Hydraulic Divisions of the American Society of Mechanical Engineers and by joint programs of the Hydrology Section of the American Geophysical Union and the Pacific Coast Section of the American Society of Agricultural Engineers and by a program of the Western Inter-State Snow Conference. Education arranged a program of five sessions devoted to selected topics and joined with Psychology in a symposium, "Can Personality be Measured?" Psychology presented a very extensive program under the auspices of the Western Psychological Association.

Sessions of the other sections were very fully represented, mostly through the medium of associated societies. Their programs consisted not only of contributed papers but also of symposia and special programs on various topics. The physicists held symposia on "Nuclear Structure" and on "Fundamental Physical Constants"; they also joined with the astronomers in a symposium on "Spectroscopy in Astrophysics." The chemists presented invitational programs on selected topics in physical chemistry and in biochemistry. The zoologists held a symposium on the "Protozoan Life Cycle"; the botanists on the "Origin and Development of North Pacific Floras" and on the "Absorption and Accumulation of Mineral Elements by Plant Cells"; the geneticists on "Genes in Relation to Characters"; and the Medical Sciences on a "Survey and Evaluation of the Present Status of Endocrine Investigations." Besides the symposia, most of the special programs noted in the preceding paragraph were made up of invitational papers.

A special feature of the meeting was the large number of joint sessions which were arranged among societies and sections with common interests. While this practise gave rise to some editorial difficulty in arranging the program, it no doubt avoided to some extent conflicts which might otherwise have been troublesome. The programs as a whole were not only extensive but also of high quality and with few exceptions the sessions were extraordinarily well attended, to such an extent that in several instances original room assignments had to be changed at the last moment to accommodate larger audiences. The ninety-fourth meeting of the association was a distinctly enjoyable and profitable event and no doubt contributed largely to an appreciation of the work of the association on the Pacific Coast.

ROY ELWOOD CLAUSEN

MADAME MARIE SKLODOWSKA CURIE

HIDDEN now by a row of beech trees Madame Marie Curie's grave lies in a little village cemetery at Sceaux, France. She died on July 4, 1934, after a brief illness. Too busy to be famous, too much in love with her work to consider fame more than a by-product of labor and zeal, she believed with her husband "No matter what it does to one, even if it makes of one a body without a soul, one must go on with one's work." Yet she found time for her two daughters, Irene and Eve, and for her friends, just as in the early days of her marriage she had found time to do her own housework, teach classes and make her discoveries.

Born in Warsaw, Poland, on November 7, 1867, Marie Sklodowska received her first scientific training and part of her heritage of patience and curiosity from her father, who was a Polish educator. From Warsaw she went first to Cracow, then to Paris to study, taking a degree in science at the university there, and began the long series of experiments which continued for nearly forty years.

When she was twenty-eight she married Pierre Curie, a physicist working on magnetism and crystallography. They had no money but they had pleasant whims, for Mme. Curie is said to have bought a tandem bicycle with her wedding money.

Their common dower was that infinite capacity for taking pains which has been defined as genius. They had also an endowment of zeal or patience or curiosity to forge ahead, even though the laboratory roof leaked rain or snow. They worked in an abandoned shed. "It was only a wooden shack," Mme. Curie said, "with a skylight roof which didn't always keep the rain out." They must have worked late and arduously, for both had much teaching to do in order to make a living. They worked in their overcoats in the winter, to make the money which might have gone for warmth to feed that other fire. "For we had to pay for our scientific research out of our own pockets"—thin pockets for the fabulous pickings they were to yield the world.

The year after the young Curies joined forces, Henri Becquerel, a friend of both, discovered the radioactive properties of uranium, an indirect consequence of the discovery of x-rays made a few months before by Röntgen. Thus the beginning of the study of radioactivity dates from 1896. Separation of the uranium left a residue three to five times as radioactive weight for weight as the uranium. She first separated from the residue a substance far more active than uranium which was named polonium in honor of Mme. Curie's native land. Working together the Curies then separated a second radioactive substance which they named radium. It is a fiercely active substance, for in the pure state radium bromide has an activity about two million times as great as an equal weight of uranium. Mme. Curie found the atomic weight of radium to be 226 and later prepared an international radium standard of about twenty-two milligrams of pure radium chloride preserved in the Bureau International des Poids et Mesures at Sèvres, near Paris. Secondary standards, checked carefully with this primary one, are kept in other places, there being one at the U. S. Bureau of Standards, Washington.

Before Professor Pierre Curie's death in 1906 when he was run over and killed by a dray in Paris streets, the couple were inseparable in the laboratory and at home, and working together did much to elucidate the properties of radium and its transformation products. They were awarded the Davy medal of the Royal Society in 1903, and the Nobel prize for physics was divided the same year between them and Henri Bec-

Henri Manuel

MME. MARIE SKLODOWSKA CURIE, 1867–1934

PROFESSOR OF RADIOACTIVITY AT THE UNIVERSITY OF PARIS. WITH HER HUSBAND, PROFESSOR PIERRE CURIE, SHE DISCOVERED RADIUM AND POLONIUM, AND FOUNDED THE SCIENCE OF RADIOACTIVITY.

querel. Professor Curie was elected to the Academy of Sciences in 1905, just one year before his death.

Mme. Curie succeeded him as professor at the University of Paris, the only woman to hold the post of university professor in France. She was also the only person to receive a second Nobel prize (1911) for isolating radium as a pure metal and for determining its atomic weight.

Theoretically, the importance to science of the discovery and isolation of radium is great because radium has played an extensive part in the growth of knowledge of the internal structure of atoms in general. The discovery of polonium and radium led to the modern analyses of radioactivity in terms of the spontaneous transformation of the radioactive bodies.

The first gift of radium to Mme. Curie from the women of America was made in May, 1921, when she visited this country. The gift was prepared by the women of America when Mme. Curie said she would rather have one gram of radium for her own use than anything in the world. Madame accepted it with the shy graciousness which characterized her dealings with fame, ending her little speech to the President after his presentation of the radium, "I thank your countrywomen in the name of humanity which we all wish so much to make happier," and then impulsively, "I love you all, my American friends, very much."

She had papers drawn making the gram of radium the property of the Curie Institute at the University of Paris, and willed it to the University "on the condition that my daughter, Irene Curie (now Mme. Joliot Curie, the wife of M. Frederic Joliot, a distinguished man of science, who subsequent to his marriage consented to take the family name of his wife) shall have during her life entire liberty to use this gram of radium."

On the occasion of her first visit to this country, Mme. Curie received honorary degrees from Yale University, Smith College and the University of Pennsylvania. When she returned in 1929, the honorary degree of Doctor of Science was conferred on her by St. Lawrence University. On this occasion Mme. Curie dedicated the Hepburn Hall of Chemistry at the university, before which a statue of her had been erected.

After the gram of radium had been presented, a gift of a yearly income of $3500 was also given, since Mme. Curie had been forced all her life to live frugally. But she did not seem to know how to spend money on herself and she used the money to rent a gram of radium for the use of the Warsaw Hospital. On October 30, 1929, she was presented with a second gram of radium in this country in order to release the income given earlier for her own use. President Hoover in making the presentation paid tribute to the fundamental importance of scientific research. Mme. Curie in accepting the gift said, "My work is very much my life, and I have been made happy by your generous support of it. . . . I feel deeply the importance of what has been said by the President of the United States about the value of pure science; this has been the creed of my life. Scientific research has its great beauty and its reward in itself; and so I have found happiness in my work."

To some extent the life of Mme. Curie was shortened by the nature of her work. For years her hands had been very tender, and press reports stated that her death was due to a form of pernicious anemia caused or hastened by exposure to the radioactive substances with which she worked.

E. P. S.

THE HOPI INDIAN STAIRWAY AT WALPI

THE Museum of the American Indian has recently acquired two large paintings of the Hopi Indian stairway to the town of Walpi, Arizona, by Mr. Frederick S. Dellenbaugh, an explorer of the canyons of the Colorado with Major Powell in 1871 and 1872. The stone slab stairway exhibits considerable engineering skill, and is the southern entrance to the town of Walpi, perched in an impregnable position seven hundred feet above the valley. No storming party could enter the town by the stairway without being annihilated with stones thrown from above. There is one northern entrance only a few feet wide leading up between perpendicular cliffs from the summit of the mesa. Years ago a band of hostile Navajos attempted an entrance by this passage and twenty-five of them were thrown over the brink to crash below. The second painting of Walpi from the north shows the narrow passage to the town, with the San Francisco mountains in the distance.

R. W. P.

THE DROUGHT AND ITS EFFECTS ON AGRICULTURAL CROPS

WEATHER reports for July, covering the entire United States, continue to establish the 1934 drought as the worst in American records. The northwest, midwest and southwest portions of the country remained not only unrelieved from what is for much of their area the fifth successive summer of drought, but July tended to intensify their distress, except in scattered local areas.

When the United States as a whole is considered, July was not only outstandingly dry but the hottest month ever known, with the all-time maximum temperature records exceeded in many places, especially in the Mid-Western States. Examination of the rainfall map of the United States, covering the same month, shows a drought by no means as wide-spread as the heat. Numerous localities, scattered throughout the country, had more than average rainfall, but those territories most severely affected by the spring drought were not among them. The Department of Agriculture also reports that the departure of average July temperatures from normal for different sections of the country is quite similar to that which occurred in July, 1901, the previous hottest month on record, though the departures from normal were somewhat larger in most places in 1934 than in 1901.

Rainfall during July could not have saved pasture, hay, and small grains generally, for their critical period had passed. The corn crop may still be saved, for its critical period occurs later, but each week with diminishing optimism the Department of Agriculture gives out successively lower estimates of the expected crop.

The shortage of water has also taken heavy toll among the livestock in the stricken area. Over 2,500,000 head of cattle have been purchased by Federal agencies and shipped to stockyards to be slaughtered and canned before they starved to death from lack of fodder.

Eight hundred thousand persons in the western half of the United States are on the relief rolls of the Emergency Relief Administration, and the total damage to growing crops and livestock has been estimated by Emergency Relief Administrator Harry Hopkins at five billion dollars, with twenty-seven million people and sixty per cent. of the country's area affected. Although serious problems of distribution will arise, the Agricultural Adjustment Administration is convinced that the nation does not face any danger of food shortage despite the drought. Secretary Wallace of the Department of Agriculture estimates that general living costs might be expected to increase from 6 to 7 per cent. as a result of the drought, food costs taken separately increasing from 15 to 20 per cent. A food and feed survey is going forward to determine just what the food supply is and orders have been given to the Department of Agriculture crop experts to send in immediately data on the food, feed and seed supply available on farms, country elevators and other storage facilities.

At the date of writing, August 15, heavy rains had come to break the drought in the most severely hit of the Middle Western regions, and although it came too late to help major crops, it may enable a fair amount of the corn crop to be salvaged, and it brought some relief from the acute water shortage.

M. L. G.